D 101. 11:9-8000/985

JAN 16 [illegible]

ORIGINAL

TM 9-8000

TECHNICAL MANUAL

IES
240

COMPLETED

777

PRINCIPLES
OF
AUTOMOTIVE
VEHICLES

DEPARTMENT OF THE ARMY

OCTOBER 1985

TECHNICAL MANUAL
NO. 9-8000

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, DC *25, October 1985*

PRINCIPLES OF AUTOMOTIVE VEHICLES

REPORTING ERRORS AND RECOMMENDING IMPROVEMENTS

You can help improve this manual. If you find any mistakes, or if you know of a way to improve the procedures, please let us know. Mail your letter, DA Form 2028 (Recommended Changes to Publications and Blank Forms), or DA Form 2028-2 located in the back of this manual directly to: Commander, US Army Tank-Automotive Command, ATTN: AMSTA-MB, Warren, MI 48397-5000. A reply will be sent to you.

TABLE OF CONTENTS

Page

PART ONE INTRODUCTION .... 1-1 - XXV

CHAPTER 1. GENERAL INFORMATION 1-1
Section I. Purpose of Manual 1-1
Section II. Organization of the Manual 1-1
Section III. History of Military Vehicles .... 1-2 -XXVI
Section IV. Characteristics of Military Vehicles 1-2
Section V. Military Vehicle Categories .... 1-3 -XVII
Section VI. Classification of Vehicles .... 1-4 -XVIII

PART TWO ENGINES 2-1

CHAPTER 2. PISTON ENGINE CHARACTERISTICS 2-1
Section I. Engine Operation 2-1
Section II. Comparison of Engine Types 2-8
Section III. Classification of Piston Engines 2-22
Section IV. Engine Measurements 2-27
Section V. Timing 2-32
Section VI. Engine Output 2-37
Section VII. Engine Efficiency 2-42

CHAPTER 3. CONVENTIONAL ENGINE CONSTRUCTION .... 3-1 -45
Section I. Cylinder Blocks, Heads, and Crankcases 3-1
Section II. Rotating and Reciprocating Parts .... 3-8 -52
Section III. Valves and Operating Mechanisms 3-27-71

CHAPTER 4. GASOLINE FUEL SYSTEMS .... 4-1 -80
Section I. Components and Their Purposes 4-1
Section II. Principles of Carburetion 4-13-92
Section III. Construction of the Basic Carburetor 4-15-94
Section IV. Systems of the Carburetor 4-17-96
Section V. Fuel Injection Systems for Gasoline Engines 4-40-119

---

*This publication supersedes TM9-8000, dated 27 January 1956

TABLE OF CONTENTS – CONTINUED

Page

Section VI. Turbochargers and Superchargers .... 4-45 -124
Section VII. Governors .... 4-48 -127
Section VIII. Characteristics of Gasoline .... 4-52 -131

CHAPTER 5. DIESEL FUEL SYSTEMS .... 5-1 -135
Section I. Characteristics of Diesel Fuels 5-1
Section II. Combustion Chamber Design .... 5-3 -137
Section III. Injection Systems .... 5-8 -142
Section IV. Fuel Supply Pumps .... 5-28 -162
Section V. Governors .... 5-30 -164
Section VI. Timing Device .... 5-33 -167
Section VII. Cold Weather Starting Aids .... 5-35 -169
Section VIII. Fuel Filters .... 5-37 -171
Section IX. Engine Retarder System .... 5-39 -173

CHAPTER 6. PROPANE FUEL SYSTEMS .... 6-1 -175
Section I. Characteristics 6-1
Section II. Basic System 6-1

CHAPTER 7. EXHAUST AND EMISSION CONTROL SYSTEMS .... 7-1 -176
Section I. Exhaust System 7-1
Section II. Emission Control System .... 7-2 -177

CHAPTER 8. LUBRICATION SYSTEM .... 8-1 -190
Section I. Purpose 8-1
Section II. Engine Oils .... 8-2 -191
Section III. Oil Pumps .... 8-5 -194
Section IV. Types of Lubrication Systems .... 8-12 -201

CHAPTER 9. ENGINE COOLING SYSEMS .... 9-1 -204
Section I. Cooling Essentials 9-1
Section II. Liquid Cooling Systems 9-1
Section III. Air Cooling Systems .... 9-11 -214

CHAPTER 10. GAS TURBINE ENGINES .... 10-1 -216
Section I. Overview 10-1
Section II. Comparison to Piston Engine .... 10-4 -219
Section III. Basic Engine Structure .... 10-6 -221
Section IV. Fuel System .... 10-15 -230
Section V. Lubrication System .... 10-16 -231
Section VI. Electrical System .... 10-18 -233

PART THREE ELECTRICAL SYSTEMS AND RELATED UNITS .... 11-1 -235

CHAPTER 11. BASIC PRINCIPLES OF ELECTRICITY 11-1
Section I. Electricity 11-1
Section II. Semiconductor Devices .... 11-4 -238
Section III. Electrical Measurements .... 11-10 -244
Section IV. Magnets .... 11-13 -247

TABLE OF CONTENTS – CONTINUED

		Page
CHAPTER 12.	BATTERIES	12-1 -252
Section I.	Construction	12-1
Section II.	Principles of Operation	12-4 -252
Section III.	Types of Batteries	12-6 -257
Section IV.	Military Applications	12-9 -260
CHAPTER 13.	CHARGING SYSTEMS	13-1 -263
Section I.	Principles of Operation	13-1
Section II.	DC Generator Principles	13-3 -265
Section III.	AC Generator Systems	13-22-284
CHAPTER 14.	STARTING SYSTEMS	14-1 -300
Section I.	Electric Starting Motor	14-1
Section II.	Control Systems	14-8 -307
CHAPTER 15.	IGNITION SYSTEMS	15-1 -311
Section I.	Battery Ignition Systems	15-1
Section II.	Magneto Ignition Systems	15-18-328
Section III.	Waterproofing Ignition Systems	15-24-334
CHAPTER 16.	LIGHTING SYSTEMS	16-1 -336
Section I.	Motor Vehicle Lighting	16-1
Section II.	Blackout Lighting	16-11-346
Section III.	Commercial Vehicle Lighting	16-12-347
CHAPTER 17.	INSTRUMENTS, GAGES, AND ACCESSORIES	17-1 -351
Section I.	Instrument Panel	17-1
Section II.	Horns	17-18-368
Section III.	Windshield Wipers	17-20-370
Section IV.	Accessories	17-21-371
Section V.	Automotive Wiring	17-26-376
CHAPTER 18.	RADIO INTERFERENCE AND SUPPRESSION	18-1 -382
Section I.	Interference	18-1
Section II.	Suppression	18-3 -384
PART FOUR	POWER TRAINS	19-1 -388
CHAPTER 19.	INTRODUCTION TO POWER TRAINS	19-1
Section I.	Purpose	19-1
Section II.	Gears	19-3 -390
Section III.	Power Train Configurations	19-14-401
CHAPTER 20.	HYDRAULIC PRINCIPLES	20-1 -405
Section I.	Principles	20-1
Section II.	Oil Pumps	20-3 -407
Section III.	Simple Hydraulic Jack	20-6 -410

TABLE OF CONTENTS – CONTINUED

Page

CHAPTER 21. CLUTCHES, FLUID COUPLINGS, AND TORQUE CONVERTERS ..... 21-1 -412
Section I. Clutches 21-1
Section II. Fluid Couplings 21-12-423
Section III. Torque Converters 21-14-425

CHAPTER 22. CONVENTIONAL TRANSMISSIONS ..... 22-1 -430
Section I. Purposes 22-1
Section II. Basic Types 22-1
Section III. Sliding Gear Transmission 22-1
Section IV. Constant Mesh Transmission ..... 22-6 -435
Section V. Gearshift Linkage ..... 22-9 -438

CHAPTER 23. AUTOMATIC TRANSMISSIONS ..... 23-1 -440
Section I. General Operation 23-1
Section II. Drive Train Mechanisms ..... 23-2 -441
Section III. Drive Train Arrangements ..... 23-6 -445
Section IV. Hydraulic System 23-12-451

CHAPTER 24. CROSS-DRIVE TRANSMISSION ..... 24-1 -470
Section I. Function 24-1
Section II. Construction and Operation 24-1

CHAPTER 25. X1100 SERIES CROSS-DRIVE TRANSMISSION ..... 25-1 -491
Section I. Function 25-1
Section II. Construction and Operation 25-1

CHAPTER 26. AUXILIARY TRANSMISSIONS, SUBTRANSMISSIONS, AND OVERDRIVES ..... 26-1 -504
Section I. Auxiliary Transmissions 26-1
Section II. Subtransmissions ..... 26-2 -505
Section III. Overdrives ..... 26-3 -506

CHAPTER 27. TRANSFER ASSEMBLIES ..... 27-1 -511
Section I. Purpose 27-1
Section II. Conventional Transfer Assemblies ..... 27-2 -512
Section III. Differential-Type Transfer Assemblies ..... 27-4 -514
Section IV. Positive Traction Transfer Case ..... 27-6 -516

CHAPTER 28. PROPELLER SHAFTS, SLIP JOINTS, AND UNIVERSAL JOINTS ..... 28-1 -521
Section I. Propeller Shafts and Slip Joints 28-1
Section II. Conventional Universal Joints ..... 28-2 -522
Section III. Constant Velocity Joints ..... 28-5 -525

TABLE OF CONTENTS – CONTINUED

Page

CHAPTER 29. DIFFERENTIALS, FINAL DRIVES, AND DRIVING AXLES .... 29-1 -530
Section I. Conventional Differentials 29-1
Section II. No-Spin Differentials .... 29-3 -532
Section III. Final Drives and Driving Axles .... 29-8 -537
Section IV. Controlled Differential 29-22-551
Section V. Wheel Vehicle Performance 29-24-553

PART FIVE CHASSIS COMPONENTS .... 30-1 -555

CHAPTER 30. SUSPENSION SYSTEMS IN WHEELED VEHICLES 30-1
Section I. Overview 30-1
Section II. Solid Axle Suspension Systems .... 30-3 -557
Section III. Independent Axle Suspension Systems .... 30-6 -560
Section IV. Heavy Vehicle Suspension .... 30-9 -563
Section V. Air-Over-Hydraulic Suspension 30-12-566
Section VI. Shock Absorbers 30-14-568
Section VII. Auxiliary Units 30-16-570

CHAPTER 31. SUSPENSION SYSTEMS IN TRACKED VEHICLES .... 31-1 -572
Section I. Principal Parts 31-1
Section II. Configurations .... 31-5 -576
Section III. Suspension Lockout System 31-5
Section IV. Spade System .... 31-7 -578

CHAPTER 32. WHEELS, TIRES, AND TRACKS .... 32-1 -579
Section I. Wheel Center Section 32-1
Section II. Wheel Rims .... 32-2 -580
Section III. Bead Locks and Bead Clips .... 32-4 -582
Section IV. Tires .... 32-5 -583
Section V. Tubes .... 32-9 -587
Section VI. Tracks 32-13-591

CHAPTER 33. STEERING SYSTEMS AND WHEEL ALINEMENT .... 33-1 -593
Section I. Steering Systems 33-1
Section II. Steering Gears .... 33-6 -599
Section III. Power Steering – Hydraulic Type .... 33-8 -601
Section IV. Air Steering 33-13-606
Section V. Four-Wheel Driving and Steering 33-15-608
Section VI. Wheel Alinement Principles 33-17-610

CHAPTER 34. BRAKING SYSTEMS .... 34-1 -615
Section I. Principles of Braking 34-1
Section II. Drum Brake Mechanisms .... 34-4 -618
Section III. Disk Brake Mechanisms 34-11-625
Section IV. Auxiliary Brake Mechanisms 34-18-632
Section V. Mechanical Brake System 34-21-635
Section VI. Hydraulic Brake System 34-23-637
Section VII. Power Braking Systems 34-29-643
Section VIII. Airbrake System 34-33-647

TABLE OF CONTENTS – CONTINUED

		Page
Section IX.	Air-Over-Hydraulic Brake System	34-40 -654
Section X.	Vacuum-Over-Hydraulic Brake System	34-41 -655
Section XI.	Electric Brake System	34-43 -657
PART SIX	HULLS, BODIES, AND FRAMES	35-1 -660
CHAPTER 35.	VEHICLE STRUCTURE	35-1
Section I.	Wheeled Vehicles	35-1
Section II.	Tracked Vehicles	35-4 -663
CHAPTER 36.	ACCESSORIES	36-1 -665
Section I.	Power Takeoff	36-1
Section II.	Winches	36-4 -668
Section III.	Tire Inflation System	36-5-669
Section IV.	Gasoline and Water Tankers	36-6-670
Section V.	Dump Truck Mechanisms	36-9-673
Section VI.	Wrecker Truck Equipment	36-12-676
Section VII.	Underwater Ventilating System	36-15-679
CHAPTER 37.	PRINCIPLES OF REFRIGERATION	37-1 -683
Section I.	General	37-1
Section II.	System Components	37-4 -686
CHAPTER 38.	TRAILERS AND SEMITRAILERS	38-1 -698
Section I.	Semitrailers	38-1
Section II.	Three-Quarter Trailers	38-4 -701
Section III.	Full Trailer	38-5 -702
Section IV.	Matching Towing Vehicle to Trailer	38-8 -705
APPENDIX	DEFINITION OF TERMS	A-1 -706
INDEX		Index 1

LIST OF ILLUSTRATIONS

Figure		Page
2-1.	Piston Engine Principles	2-1
2-2.	Piston Engine Operation	2-2
2-3.	Piston and Crankshaft	2-2
2-4.	Piston to Crankshaft Relationship	2-3
2-5.	Intake and Exhaust Ports	2-3
2-6.	Intake and Exhaust Valves	2-3
2-7.	Piston Positions	2-4
2-8.	Four-Stroke Cycle Operation	2-5
2-9.	Valve Train Operation	2-6
2-10.	Timing Gears	2-7
2-11.	Flywheel	2-7
2-12.	Internal Combustion Engine Versus External Combustion Engine	2-8
2-13.	Two-Stroke Cycle Engine	2-8

LIST OF ILLUSTRATIONS – CONTINUED

Figure Page

2-14. The Two-Stroke Cycle 2-9
2-15. The Four-Stroke Cycle Diesel 2-10
2-16. Comparison of Diesel and Gasoline Engine Compression Strokes 2-11
2-17. Comparison of Diesel and Gasoline Engine Intake Strokes 2-12
2-18. Comparison of Gasoline and Diesel Engine Regulation of Power 2-12
2-19. Four-Stroke Cycle Diesel 2-13
2-20. Multifuel Engine 2-14
2-21. The Two-Stroke Cycle Diesel Engine 2-15
2-22. The Two-Stroke Diesel Cycle 2-16
2-23. Comparison of Two- and Four-Stroke Cycle Diesel Power Stroke Lengths 2-17
2-24. Measuring Crankshaft Rotation 2-18
2-25. Typical Multiple-Cylinder Configurations 2-18
2-26. Power Delivery in One-, Four-, Six-, and Eight-Cylinder Engines 2-19
2-27. The Rotary Engine 2-20
2-28. The Rotary Engine Cycle 2-21
2-29. Speed Relationship of Rotor to Eccentric Shaft 2-21
2-30. Two-Rotor Configuration 2-22
2-31. Typical Air-Cooled Arrangement 2-22
2-32. Typical Liquid-Cooled Arrangement 2-23
2-33. Typical Flathead Cylinder Head 2-23
2-34. T-Head Engine 2-23
2-35. L-Head Engine 2-24
2-36. Typical Overhead Valve Cylinder Head 2-24
2-37. I-Head Engine 2-24
2-38. Single Overhead Camshaft Configurations 2-25
2-39. Double Overhead Camshaft Configurations 2-25
2-40. F-Head Engine 2-26
2-41. Typical Cylinder Arrangements 2-26
2-42. Bore, Stroke, and Displacement 2-27
2-43. Illustrating the Weight of Air 2-28
2-44. Atmospheric Pressure at Sea Level 2-29
2-45. Vacuum in the Cylinder 2-29
2-46. Demonstrating Volumetric Efficiency 2-30
2-47. Fresh Air Intake System 2-31
2-48. Port Design Consideration 2-31
2-49. Compression Ratio 2-32
2-50. Increasing Compression Ratio 2-32
2-51. Ignition Timing 2-33
2-52. Effect of Increasing Ignition Timing 2-33
2-53. Opening and Closing Points of the Valve 2-34
2-54. Valve Opening Duration 2-35
2-55. Valve Timing Diagram Showing Valve Overlap 2-36
2-56. Crankshaft Rotational Periods of Imperceptible Piston Movement 2-36

LIST OF ILLUSTRATIONS – CONTINUED

Figure		Page
2-57.	One Foot Pound of Work	2-37
2-58.	Forms of Energy	2-38
2-59.	Horsepower	2-38
2-60.	Torque Effect	2-39
2-61.	Prony Brake	2-39
2-62.	Dynamometers	2-40
2-63.	Conversion of Torque to Work	2-41
2-64.	Torque Output Versus Speed	2-41
2-65.	Torque-Horsepower-Speed Relationship	2-41
2-66.	Pulley System with a 90-Percent Efficiency	2-42
3-1.	Liquid-Cooled Cylinder Block	3-1
3-2.	Requirements of a Cylinder	3-2
3-3.	Cylinder Sleeves	3-3
3-4.	Engine Crankcase	3-4
3-5.	Typical Cylinder Head Installation	3-4
3-6.	Combustion Chamber	3-5
3-7.	Valves and Ports	3-5
3-8.	Cylinder Head Cooling	3-6
3-9.	Cylinder Head Sealing	3-6
3-10.	Air-Cooled Cylinder	3-7
3-11.	Air-Cooled Crankcase	3-7
3-12.	Piston	3-8
3-13.	Controlling Piston Expansion	3-9
3-14.	Cam-Ground Piston	3-9
3-15.	Full- and Partial-Skirted Pistons	3-10
3-16.	Piston Structure	3-10
3-17.	Purpose of Piston Rings	3-11
3-18.	Piston Ring Types and Description	3-12
3-19.	Configurations of Piston Rings	3-12
3-20.	Types of Compression Rings	3-13
3-21.	Operation of Compression Rings	3-14
3-22.	Heat Dam	3-15
3-23.	Ring Gap	3-15
3-24.	Ring Gap Variations	3-15
3-25.	Staggered Ring Gaps	3-15
3-26.	Top Ring Groove Insert	3-16
3-27.	Oil Control Rings	3-16
3-28.	Piston Ring Expanders	3-17
3-29.	Piston Ring Wear-In	3-17
3-30.	Piston Pin	3-18
3-31.	Piston Pin Construction	3-18
3-32.	Piston Pin Configurations	3-19
3-33.	Connecting Rod Constructions	3-19
3-34.	Crankshaft Construction	3-20
3-35.	Crankshaft Throw Arrangements	3-21
3-36.	Crankshaft Counterweights	3-22
3-37.	Vibration Damper	3-23

LIST OF ILLUSTRATIONS – CONTINUED

Figure		Page
3-38.	Crankshaft Lubrication Passages	3-23
3-39.	Crankshaft Bearings	3-24
3-40.	Typical Insert Bearing Installation	3-24
3-41.	Bearing Materials	3-25
3-42.	Bearing Requirements	3-25
3-43.	Connecting Rod Lubrication	3-25
3-44.	Crankshaft Main Bearings	3-26
3-45.	Flywheel	3-26
3-46.	Valve Configurations	3-27
3-47.	Exhaust Valve Configurations	3-28
3-48.	Valve Seats	3-28
3-49.	Valve Guides	3-29
3-50.	Valve Springs, Retainers, and Seals	3-29
3-51.	Valve Rotators	3-30
3-52.	Camshaft Support	3-30
3-53.	Driving the Camshaft	3-31
3-54.	Auxiliary Camshaft Functions	3-31
3-55.	Mechanical Tappets	3-32
3-56.	Hydraulic Tappets	3-33
3-57.	Tappet-to-Cam Lobe Relationship	3-33
3-58.	Push Rod	3-34
3-59.	Rocker Arms	3-34
3-60.	Examples of Adjusting Valve Clearance	3-35
4-1.	Common Fuel Tank Locations	4-1
4-2.	Typical Removable Fuel Tank Construction	4-2
4-3.	Typical Fuel Cell Installation	4-2
4-4.	Bladder-Type Fuel Cell	4-3
4-5.	Typical Fuel Filter Locations	4-3
4-6.	Fuel Filter Operation	4-3
4-7.	Fuel Filter Configurations	4-4
4-8.	Fuel Filter Element Configurations	4-5
4-9.	Mechanical Nonpositive Pump	4-6
4-10.	Mechanical Positive Pump Installation	4-7
4-11.	Double Action Pump	4-7
4-12.	Bellows-Type Electric Fuel Pump	4-8
4-13.	Vane-Type Electric Pump	4-8
4-14.	Typical Intake Manifold	4-9
4-15.	Ram Induction Manifold	4-10
4-16.	Exhaust-Heated Intake Manifold	4-10
4-17.	Water-Heated Intake Manifold	4-11
4-18.	Air Filter	4-12
4-19.	Wet-Type Air Filter	4-12
4-20.	Dry-Type Air Filter	4-13
4-21.	Example of Atomization	4-14
4-22.	Venturi Effect	4-14
4-23.	Secondary Venturi	4-15

LIST OF ILLUSTRATIONS – CONTINUED

Figure Page

4-24. Air-Fuel Ratio Demonstration 4-15
4-25. Throttle Valve 4-15
4-26. Float Circuit 4-16
4-27. Controlling Fuel Bowl Pressure 4-16
4-28. Main Jet 4-17
4-29. Idle and Low-Speed Systems 4-18
4-30. High-Speed Systems 4-19
4-31. Vacuum Power Jet 4-19
4-32. Vacuum-Operated Metering Rod 4-20
4-33. Mechanically Operated Metering Rod 4-20
4-34. Acclerator Pump Circuit 4-21
4-35. Diaphragm Accelerator Pump 4-22
4-36. Duration Spring 4-23
4-37. Choke Valve Operation 4-24
4-38. Manual Choke System 4-24
4-39. Automatic Choke System 4-25
4-40. Electric Choke 4-25
4-41. Engine Coolant Heated Choke 4-26
4-42. Well-Type Exhaust Heated Choke 4-26
4-43. Exhaust Heat-Tube Type Choke 4-27
4-44. Choke Vacuum Piston 4-27
4-45. Choke Piston Integral with Choke Housing 4-27
4-46. Remote Chock Pulloff 4-28
4-47. Two-Stage Choke Pulloff 4-28
4-48. Fast Idle Cam Operation 4-29
4-49. Chock Unloader 4-29
4-50. Two-Barrel Carburetor with Fixed Linkage 4-30
4-51. Mechanical Progressive Linkage Operation 4-31
4-52. Vacuum Progressive Linkage Operation 4-32
4-53. Secondary Air Valve Operation 4-33
4-54. Typical Four-Barrel Carburetor 4-33
4-55. Updraft, Downdraft, and Sidedraft Carburetors 4-34
4-56. Primer System 4-34
4-57. Degasser System 4-35
4-58. Hot Idel Compensator 4-36
4-59. Throttle Return Dashpot 4-36
4-60. Antidiesel/Air-Conditioning Solenoid Operation 4-37
4-61. Idle Solenoid System Operation 4-38
4-62. Heated Air Intake System Operation 4-39
4-63. Mechanical-Timed Injection 4-41
4-64. Electronic-Timed Injection 4-42
4-65. Continuous Injection 4-43
4-66. Throttle Body Injection 4-44
4-67. Turbocharger 4-46
4-68. Centrifugal Supercharger 4-47
4-69. Rootes Supercharger 4-47
4-70. Vane-Type Supercharger 4-47
4-71. Pressure Box 4-48
4-72. Centrifugal Governor 4-49
4-73. Velocity-Vacuum Governor – Type I 4-50

LIST OF ILLUSTRATIONS – CONTINUED

Figure		Page
4-74.	Velocity-Vacuum Governor – Type II	4-51
4-75.	Centrifugal-Vacuum Governor	4-52
4-76.	Normal Combustion	4-53
4-77.	Detonation	4-54
4-78.	Preignition	4-55
5-1.	Fuel Density Compensator	5-3
5-2.	Open Combustion Chamber	5-4
5-3.	Precombustion Chamber	5-5
5-4.	Turbulence Chamber	5-5
5-5.	Spherical Chamber	5-6
5-6.	General System Operation	5-9
5-7.	Multiple Unit Injection Pump	5-10
5-8.	Multiple Unit Injector	5-11
5-9.	Injector Nozzles	5-13
5-10.	Wobble Plate Injection Pump	5-15
5-11.	Distributor Injection System	5-17
5-12.	Fuel Metering System	5-18
5-13.	Distributor-Type Unit Injectors	5-18
5-14.	Unit Injection System	5-19
5-15.	Unit Injector Operation	5-20
5-16.	Pressure-Timed Injection System	5-22
5-17.	Pressure-Timed Gear Pump	5-23
5-18.	Pressure-Timed Delivery Injector Operation	5-24
5-19.	PSB Distributor Injection System	5-25
5-20.	PSB Injection Pump	5-26
5-21.	PSB Injection Pump Operation	5-27
5-22.	Plunger-Type Supply Pump	5-29
5-23.	Mechanical (Centrifugal) Governor	5-31
5-24.	Vacuum-Operated Governor	5-32
5-25.	Timing Device	5-33
5-26.	Timing Device Operation	5-34
5-27.	Manifold Flame Heater System	5-36
5-28.	Ether Injection System	5-37
5-29.	Primary Fuel Filter	5-38
5-30.	Secondary Fuel Filter	5-39
5-31.	Jacobs Engine Brake	5-40
6-1.	Liquefied Petroleum Gas System	6-1
7-1.	Typical Exhaust System	7-1
7-2.	Exhaust Manifold	7-2
7-3.	Manifold Heat Control Valve	7-3
7-4.	Muffler	7-4
7-5.	Vehicle Emissions	7-4
7-6.	Draft Tube System	7-5
7-7.	PCV System	7-6
7-8.	Catalytic Converter	7-8
7-9.	Air Pump System	7-10
7-10.	Naturally Aspirated System	7-11

LIST OF ILLUSTRATIONS – CONTINUED

Figure		Page
7-11.	EGR System	7-12
7-12.	Fuel Evaporation System	7-14
8-1.	Typical Engine Lubrication System	8-1
8-2.	How Oil Lubricates	8-3
8-3.	Sources of Oil Contamination	8-4
8-4.	Rotor Type Oil Pump	8-6
8-5.	Gear-Type Oil Pump	8-6
8-6.	Oil Pickup and Strainer	8-7
8-7.	Oil Filters	8-8
8-8.	Oil Filtering Mediums	8-9
8-9.	Filter System Configurations	8-10
8-10.	Oil Temperature Regulator	8-11
8-11.	Oil Cooler	8-11
8-12.	Oil Level Indicator	8-11
8-13.	Oil Pressure Regulator	8-12
8-14.	Splash-Type Lubrication System	8-12
8-15.	Combination Splash and Force-Feed Lubrication System	8-13
8-16.	Force-Feed Lubrication System	8-13
8-17.	Full Force-Feed Lubrication System	8-14
9-1.	Liquid-Cooled System	9-2
9-2.	Engine Radiator Construction	9-3
9-3.	Water Pump Construction	9-4
9-4.	Viscous Fan Clutch	9-5
9-5.	Electrically Motorized Fan	9-5
9-6.	Variable Pitch Fan	9-6
9-7.	Bellows-Type Thermostat	9-7
9-8.	Pellet-Type Thermostat	9-8
9-9.	Coolant Bypass	9-9
9-10.	Pressure Cap	9-10
9-11.	Expansion Tank	9-10
9-12.	Closed Cooling System	9-11
9-13.	Air Cooling System	9-12
10-1.	Early Examples of Gas Turbine Engines	10-1
10-2.	Theory of Gas Turbine Engine	10-3
10-3.	Comparison of Piston Engine to Turbine Engine	10-4
10-4.	The Otto Cycle	10-5
10-5.	The Brayton Cycle	10-6
10-6.	Air Inlet Section	10-7
10-7.	Axial Compressor	10-8
10-8.	Centrifugal Compressor	10-9
10-9.	Combustion Chamber	10-10
10-10.	Typical Recouperator	10-11
10-11.	Recouperator Plate Detail	10-12
10-12.	Radial Inflow Turbine	10-12
10-13.	Axial Flow Design	10-13
10-14.	Impulse Turbine	10-13

LIST OF ILLUSTRATIONS – CONTINUED

Figure Page

10-15. Reaction Turbine 10-13
10-16. Impulse-Reaction Turbine Blade 10-14
10-17. Turbine Construction 10-14
10-18. Gas Turbine Fuel Pumps 10-15
10-19. Fuel Injection Nozzles 10-16
10-20. Typical Oil Storage Tank 10-17
10-21. Typical Fuel-Oil Cooler 10-18
10-22. Typical Ignition System 10-19
10-23. Typical Electric Starter 10-19

11-1. Composition of Matter 11-1
11-2. Composition of Electricity 11-3
11-3. Conductors and Insulators 11-3
11-4. Covalent Bonding of Silicon 11-5
11-5. Phosphorus-Doped Silicon 11-5
11-6. Boron-Doped Silicon 11-6
11-7. Hole Movement Theory 11-6
11-8. Diode Operation 11-7
11-9. Zener Diode Operation 11-8
11-10. Transistor Configurations 11-8
11-11. Transistor Operation 11-9
11-12. Basic Electrical Circuit 11-11
11-13. Typical Automotive Circuit 11-12
11-14. Circuit Configurations 11-13
11-15. Magnetic Lines of Force 11-14
11-16. Bar and Horseshoe Magnet 11-14
11-17. Effects Between Magnetic Poles 11-14
11-18. Electromagnetism 11-15
11-19. Electromagnetism in a Wire Loop 11-15
11-20. Electromagnetism in a Wire Coil 11-16
11-21. Left-Handed Rule 11-16
11-22. Electromagnetic Induction 11-17

12-1. Cross Section of a Typical Storage Battery 12-1
12-2. Plate Construction 12-2
12-3. Cell Group Construction 12-2
12-4. Battery Cell Elements 12-3
12-5. Battery Container Construction 12-4
12-6. Battery Discharge/Charge Cycle 12-5
12-7. Comparison of Discharge Characteristics 12-9
12-8. Battery Installation Configurations 12-11

13-1. Simple Single-Loop Generator 13-2
13-2. Multiple-Loop Generator 13-2
13-3. AC and DC Flow 13-3
13-4. Field Winding Configurations 13-4
13-5. Shunt-Wound Generator 13-5
13-6. Shunt-Wound Generator Operation 13-5
13-7. Generator Drive Systems 13-6

LIST OF ILLUSTRATIONS – CONTINUED

Figure Page

13-8. Cutout Relay 13-7
13-9. Reverse-Series Field 13-8
13-10. Vibrating Point Voltage Regulator 13-9
13-11. Vibrating Point Regulator Circuit 13-11
13-12. Carbon-Pile Regulator and Circuit 13-12
13-13. Third-Brush Regulation 13-13
13-14. Light Switch Control of a Third-Brush Generator 13-15
13-15. Step-Voltage Control of a Third-Brush Generator 13-16
13-16. Thermostatic Control of a Third-Brush Generator 13-17
13-17. Split-Series Field Regulation 13-17
13-18. Main and Auxiliary Generators 13-19
13-19. Paralleling Relays 13-21
13-20. Carbon-Pile Regulation of Generators 13-22
13-21. Typical Alternator 13-23
13-22. Diode Arrangement in Rectifier Bridge 13-24
13-23. Comparison for Outputs of AC and DC Generators 13-25
13-24. Simple AC Generator 13-25
13-25. Rotor Construction 13-26
13-26. Stator Construction 13-26
13-27. Rotor-to-Stator Relationship 13-27
13-28. Wound-Pole Alternator 13-27
13-29. Lundell Alternator 13-28
13-30. Lundell Inductor 13-29
13-31. Inductor Alternator 13-30
13-32. Brushless-Rotating Rectifier 13-31
13-33. Generator Cooling 13-32
13-34. AC and DC Regulator Comparison 13-33
13-35. Vibrating Point Regulating Circuit 13-34
13-36. Transistorized Voltage Regulator 13-35
13-37. Solid-State Regulator Circuit 13-36
13-38. Fuel Pressure Field Switch Circuit 13-36
13-39. Field Relay and Warning Light Circuit 13-37

14-1. Simple DC Motor 14-1
14-2. Automotive Starting Motor 14-2
14-3. Typical Starting Motor 14-3
14-4. Field Winding Configurations 14-4
14-5. Starter Drives 14-4
14-6. Gear Reduction Starter 14-5
14-7. Overrunning Clutch 14-5
14-8. Pedal Shift Starter 14-6
14-9. Solenoid Shift Starter 14-7
14-10. Bendix Starter Drive 14-8
14-11. Key and Pushbutton Control Circuits 14-9
14-12. Vacuum Lockout Switch Control Circuit 14-9
14-13. Generator Lockout Relay 14-10
14-14. Oil Pressure Lockout Circuit 14-11

LIST OF ILLUSTRATIONS – CONTINUED

Figure		Page
15-1.	Principles of Self-Induction	15-2
15-2.	Capacitor Action	15-3
15-3.	Typical Automotive Ignition System	15-4
15-4.	Ignition Switch and Positions	15-5
15-5.	Ignition Coil Construction	15-5
15-6.	Ignition Distributor	15-6
15-7.	Typical Spark Plug Construction and Heat Range Descriptions	15-7
15-8.	Resistor Spark Plugs	15-7
15-9.	Booster Gap Spark Plugs	15-7
15-10.	Ballast Resistor	15-8
15-11.	Secondary Cable Construction	15-8
15-12.	Parallel-Connected Multiple Contacts	15-9
15-13.	Alternately Actuated Multiple Contacts	15-10
15-14.	Dual-Circuit Contact Points	15-11
15-15.	Twin-Ignition System	15-12
15-16.	Transistorized Point Ignition	15-13
15-17.	Solid-State Ignition System	15-14
15-18.	Capacitive-Discharge Ignition System	15-15
15-19.	Vacuum Timing Controls	15-16
15-20.	Centrifugal Timing Controls	15-17
15-21.	Computerized Timing Control System	15-18
15-22.	Typical Magneto System	15-19
15-23.	Magneto Generator	15-20
15-24.	Magneto Control System	15-22
15-25.	Waterproof Ignition System	15-25
16-1.	Typical Automotive Lighting Circuit	16-1
16-2.	Lamp Construction and Configurations	16-2
16-3.	Focused Light Beam Construction	16-3
16-4.	Automotive Headlamp Pattern	16-5
16-5.	Automotive Headlamp Configurations	16-6
16-6.	Sealed-Beam Headlamp Construction	16-6
16-7.	Instrument-Mounted Headlamp Switch	16-7
16-8.	Turn Signal Lever-Mounted Headlamp Switch	16-8
16-9.	Blackout Light/Headlamp Switch	16-9
16-10.	Floor-Mounted Dimmer Switch	16-10
16-11.	Turn Signal Lever-Mounted Dimmer Switch	16-10
16-12.	Overload Breakers	16-10
16-13.	Demonstration of Circuit Breaker Operation	16-10
16-14.	Demonstration of Fuse Operation	16-11
16-15.	Blackout Driving Light	16-11
16-16.	Blackout Stop and Marker Light	16-12
16-17.	Military Composite Light	16-12
16-18.	Typical Turn Signal Switch	16-13
16-19.	Typical Turn Signal Wiring Diagram	16-13
16-20.	Turn Signal Flasher	16-14
16-21.	Typical Backup Light System	16-14
16-22.	Stoplight Switch Configurations	16-15
16-23.	Typical Stoplight System	16-15

LIST OF ILLUSTRATIONS – CONTINUED

Figure		Page
17-1.	Typical Instrument Panel	17-1
17-2.	Ammeter Operation	17-2
17-3.	Voltmeter Operation	17-2
17-4.	Low-Voltage Warning Lamp	17-3
17-5.	No-Charge Indicator Lamp	17-3
17-6.	Thermostatic Fuel Gage: Self-Regulating	17-4
17-7.	Thermostatic Fuel Gage: Eternally Regulated	17-5
17-8.	Thermostatic Fuel Gage: Differential Type	17-6
17-9.	Magnetic Fuel Gage	17-7
17-10.	Types of Sending Units for Pressure Gages	17-8
17-11.	Mechanical Pressure Gages	17-9
17-12.	Oil Pressure Warning Lamp	17-9
17-13.	Types of Temperature Gage Sending Units	17-9
17-14.	Mechanical Temperature Gage	17-11
17-15.	Temperature Warning Lights	17-11
17-16.	Mechanical Speedometer Installation	17-12
17-17.	Mechanical Speedometer Operation	17-13
17-18.	Odometer Operation	17-14
17-19.	Mechanical Tachometer and Engine Hours Gage	17-14
17-20.	Electric Speedometer and Tachometer Operation	17-15
17-21.	Tachograph	17-15
17-22.	Vacuum Gage Readings	17-17
17-23.	Electric Horn, Vibrator Type	17-18
17-24.	Horn Circuit Using a Relay	17-19
17-25.	Air Horns	17-19
17-26.	Electric Wipers	17-20
17-27.	Wiper Arm and Blade	17-21
17-28.	Auxiliary Power Receptacle	17-22
17-29.	Typical Heating Ventilation and Air-Conditioning System	17-23
17-30.	Typical Heater Core	17-24
17-31.	Cable-Operated Mode Doors	17-24
17-32.	Vacuum-Operated Mode Doors	17-25
17-33.	Wiring Harnesses	17-26
17-34.	Harness Bindings	17-27
17-35.	Wire Identification	17-28
17-36.	Electrical Terminals	17-29
17-37.	Wire Receptacles and Connectors	17-30
18-1.	Typical Ignition System	18-2
18-2.	Radio Interference Suppression Filters and Cable Shielding	18-4
18-3.	Examples of Bonding	18-5
19-1.	Power Takeoff	19-2
19-2.	Power Takeoff Driving Winch	19-3
19-3.	Mechanical Advantage	19-4
19-4.	Internal and External Gears	19-5
19-5.	Types of Gears	19-5
19-6.	Planetary Gear System	19-6
19-7.	Laws of Planetary Gearing	19-7
19-8.	Typical Locations of Antifriction Bearings	19-8

LIST OF ILLUSTRATIONS – CONTINUED

Figure Page

19-9. Typical Ball Bearings 19-9
19-10. Typical Roller Bearings 19-9
19-11. Typical Tapered Roller Bearings 19-10
19-12. Typical Needle Bearings 19-11
19-13. Typical Sealed Bearings 19-11
19-14. Synthetic Rubber Oil Seals 19-12
19-15. Wick Seals 19-13
19-16. Typical Gaskets 19-14
19-17. Typical Front-Wheel Drive Configuration 19-15
19-18. Typical Rear-Wheel Drive Configurations 19-15
19-19. Typical Four-Wheel Drive Power Transmission 19-16
19-20. Typical Six-Wheel Drive Power Transmission 19-16
19-21. Typical Eight-Wheel Drive Vehicle 19-17

20-1. Compressibility of Gases and Liquids 20-1
20-2. Pascal's Law 20-2
20-3. Mechanical Advantage 20-3
20-4. Gear-Type Pumps 20-3
20-5. Rotary Pumps 20-4
20-6. Vane Type 20-5
20-7. Internal-External Gear Pump 20-5
20-8. Simple Hydraulic Jack 20-7

21-1. Components of Typical Clutch 21-1
21-2. Clutch-Drive Plate with Flexible Center 21-2
21-3. Single, Large Coil Spring Clutch 21-3
21-4. Cross-Sectional View of Large Coil Spring Clutch 21-4
21-5. Diaphragm Spring Clutch Operation 21-5
21-6. Diaphragm Spring Clutch – Disassembled View 21-6
21-7. Clutch Activation 21-6
21-8. Mechanical Operating Systems 21-7
21-9. Hydraulic Operating Systems 21-8
21-10. Single Dry Plate Clutch 21-9
21-11. Clutch Disk with Two Driven Disks 21-10
21-12. Multiple-Disk Clutch 21-11
21-13. Semicentrifugal Clutch – Cross-Sectional View 21-12
21-14. Fluid Coupling – Disassembled View 21-13
21-15. Fluid Coupling – Schematic View 21-14
21-16. Torque Converter – Partial Cutaway View 21-15
21-17. Torque Converter Cutaway so Curvature of Vanes and Oil Flow is Visible 21-16
21-18. Primary and Secondary Stators Showing Freewheeling Rotors 21-17
21-19. Torque Converter with Lockup Clutch 21-18

22-1. Transmission Shifting Mechanism and Control Lever 22-2
22-2. Transmission Gears in Neutral Position 22-3
22-3. Transmission Gears in Low Position 22-4
22-4. Transmission Gears in Intermediate Position 22-4
22-5. Transmission Gears in High Position 22-5
22-6. Transmission Gears in Reverse Position 22-5

LIST OF ILLUSTRATIONS – CONTINUED

Figure Page

22-7. Constant Mesh Transmission Assembly 22-7
22-8. Main Shaft Assembly 22-8
22-9. Synchronizers 22-8
22-10. Synchromesh Transmission 22-9
22-11. Gearshift Linkage 22-10

23-1. Automatic Transmission Cross-Sectional View 23-1
23-2. Multiple-Disk Clutch 23-2
23-3. Multiple-Disk Clutch Operation 23-3
23-4. Brake Band 23-4
23-5. Brake Band Operation 23-5
23-6. Overrunning Clutches 23-5
23-7. Typical Two-Speed Automatic Transmission Utilizing Compound Planetary Drive Train 23-6
23-8. Compound Planetary Drive Train Operation 23-7
23-9. Simpson Drive Train Operation 23-9
23-10. Typical Hydraulic Supply System 23-12
23-11. Typical Transmission Hydraulic Pump 23-13
23-12. Typical Torque Converter Feed Circuit 23-15
23-13. Typical Range Control Circuit 23-17
23-14. Manual Valve Operation 23-18
23-15. Operation of the Governor 23-19
23-16. Typical Governor Pressure Versus Speed 23-20
23-17. Shift Valve 23-20
23-18. Transmission Hydraulic System in Neutral 23-21
23-19. Transmission Hydraulic System in Low (L) Range 23-22
23-20. Transmission Hydraulic System in Reverse (R) 23-23
23-21. Transmission Hydraulic System in Drive (D) – Low Range 23-25
23-22. Transmission Hydraulic System in Drive (D) – Direct Range 23-26
23-23. Transmission Hydraulic System in Drive (D) – Forced Downshift Range 23-27
23-24. Operation of the Accumulator 23-28
23-25. Transmission Modulator 23-29
23-26. Hydraulic Schematic of a Typical Three-Speed Automatic Transmission 23-30

24-1. Cross-Drive Transmission – Right Front View 24-2
24-2. Cross-Drive Transmission – Disassembled into Main Subassemblies 24-3
24-3. Torque Converter Construction and Principles of Operation 24-4
24-4. Power Flow through Cross-Drive Transmission in Low Range 24-5
24-5. Power Flow through Cross-Drive Transmission in High Range 24-7
24-6. Power Flow through Cross-Drive Transmission in Reverse Range 24-9
24-7. Power Flow through Cross-Drive Transmission during Left Steering in Neutral Range 24-11
24-8. Power Flow through Cross-Drive Transmission during Right Steering in Neutral Range 24-14
24-9. Power Flow through Cross-Drive Transmission during Left Steering in Low Range 24-17

LIST OF ILLUSTRATIONS – CONTINUED

Figure Page

24-10. Range Control Valve and Steering Control Valve Schematic Diagram 24-20
24-11. Brake – Schematic View 24-21

25-1. X1100 Transmission – External View 25-2
25-2. X1100 Transmission – Internal View 25-3
25-3. Lockup Torque Converter 25-3
25-4. Power Flow through X1100 Transmission in Neutral 25-4
25-5. Power Flow through X1100 Transmission in First Range 25-5
25-6. Power Flow through X1100 Transmission in Second Range 25-6
25-7. Power Flow through X1100 Transmission in Third Range 25-7
25-8. Power Flow through X1100 Transmission in Fourth Range 25-8
25-9. Power Flow through X1100 Transmission in Reverse 1 Range 25-9
25-10. Power Flow through X1100 Transmission in Reverse 2 Range 25-10
25-11. Hydrostatic Steer Unit-Zero Steer 25-10
25-12. Hydraulic Diagram for X1100 Transmission-Zero Steer 25-11
25-13. Hydrostatic Steer Unit in Left-Steer Position 25-12
25-14. Hydrostatic Steer Unit in Right-Steer Position 25-12
25-15. Final Drive Assembly 25-13

26-1. Typical Location of Auxiliary Transmission 26-1
26-2. Auxiliary Transmission – Sectional View 26-2
26-3. Automatic Subtransmission 26-2
26-4. Overdrive Unit 26-3
26-5. Overdrive in Locked-Out Position 26-4
26-6. Overdrive in Engaged Position 26-6
26-7. Typical Overdrive Control Circuit 26-7

27-1. Typical Driveline Arrangement with Transfer Assembly 27-1
27-2. Typical Conventional Transfer Assembly for 6 x 6 Vehicles 27-2
27-3. Typical Conventional Transfer Assembly Using Chain Drive for Front Axle 27-3
27-4. Power Flow in Transfer Assembly 27-3
27-5. Differential-Type Transfer Assembly 27-5
27-6. Transfer Assembly Sprag Unit 27-7
27-7. Positive Traction Transfer Case Operation 27-8
27-8. Air-Control Diagram of Transmission and Transfer Assembly Using an Air-Controlled Double-Sprag Unit 27-9

28-1. Typical Propeller Shaft and Slip Joint 28-1
28-2. Typical Universal Joint 28-2
28-3. Speed Fluctuations Caused by Conventional Universal Joints 28-3
28-4. Various Conventional Universal Joints 28-4
28-5. Rzeppa Constant Velocity Joint 28-6
28-6. Bendix-Weiss Constant Velocity Joint 28-7
28-7. Tracta Constant Velocity Joint 28-8
28-8. Double Cross and Roller Constant Velocity Joint 28-9

LIST OF ILLUSTRATIONS – CONTINUED

Figure		Page
29-1.	Differential Operation	29-1
29-2.	Conventional Differential	29-2
29-3.	Comparison of Conventional and High-Traction Differential Gears	29-3
29-4.	Sprag-Type No-Spin Differential	29-4
29-5.	Silent-Type No-Spin Differential	29-5
29-6.	Multiple Plate Clutch No-Spin Differential	29-6
29-7.	Cone Clutch-Type No-Spin Differential	29-7
29-8.	Gear Drive Configurations	29-8
29-9.	Worm Gear Drive	29-9
29-10.	Hypoid Gear Drive	29-10
29-11.	Axle Configurations	29-11
29-12.	Independent Live Axle Suspension	29-12
29-13.	Double-Reduction Drive Axle	29-13
29-14.	Dual-Ratio Drive Axle	29-14
29-15.	Double-Reduction Dual-Ratio Drive Axle	29-15
29-16.	Gear Carrier with Power Divided	29-16
29-17.	Front Live Axle Assembly and Four-Wheel Drive Installation	29-18
29-18.	Helical Gear Drive for Steerable Wheels	29-19
29-19.	Tandem Axles with Individual Propeller Shafts	29-20
29-20.	Tandem Axles with Power Divider	29-21
29-21.	Controlled Differential	29-22
29-22.	Controlled Differential with Final Drive	29-23
30-1.	Leaf Springs	30-1
30-2.	Coil Springs	30-2
30-3.	Torsion Bar	30-3
30-4.	Hotchkiss Drive	30-3
30-5.	Torque Tube Drive	30-4
30-6.	Torque Arm Drive	30-4
30-7.	Coil Spring and Control Rod Drive	30-5
30-8.	Dead Front Axle	30-6
30-9.	Freewheeling Independent Suspension	30-7
30-10.	Driven Parallel Wishbone Coil Spring Front Suspension	30-7
30-11.	Driven Parallel Wishbone Torsion Bar Suspension	30-8
30-12.	Swinging-Arm Independent Rear Suspension	30-8
30-13.	MacPherson Strut Suspension	30-9
30-14.	Auxiliary Spring Suspension	30-10
30-15.	Variable Load Spring Arrangement	30-11
30-16.	Bogie Axle Configuration	30-11
30-17.	Air Compressor	30-12
30-18.	Pressure Regulator Valve	30-13
30-19.	Height Control Valve	30-13
30-20.	Air Shock Absorber	30-13
30-21.	Single-Acting Cam-Operated Shock Absorber	30-15
30-22.	Vane-Type Shock Absorbers	30-15
30-23.	Direct-Acting Shock Absorber	30-16
30-24.	Pusher Axle and Controls	30-17

LIST OF ILLUSTRATIONS – CONTINUED

Figure Page

31-1. The Volute Spring 31-2
31-2. Torsion Bar Spring Used in Tracked Vehicles 31-2
31-3. Road Wheels 31-3
31-4. Idler Wheel Operation 31-4
31-5. Hydromechanical Lockout System 31-6
31-6. The Spade System 31-7

32-1. Disk Wheel 32-1
32-2. Cast Aluminum Wheel 32-1
32-3. Wire Wheel 32-1
32-4. Drop Center Rim 32-2
32-5. Semidrop Center Rim 32-2
32-6. Safety Rim 32-3
32-7. Split Rims 32-3
32-8. Bead Locks 32-4
32-9. Bead Clips 32-5
32-10. Radial Tire Construction 32-5
32-11. Bias-Ply Tire Construction 32-6
32-12. Solid Tire Construction 32-6
32-13. Directional Mud and Snow Tread 32-7
32-14. Nondirectional Mud and Snow Tread 32-7
32-15. Cross-Country Tread 32-7
32-16. Regular Treads 32-8
32-17. Rock Service Tread 32-8
32-18. Earthmover Tread 32-8
32-19. Standard Tube 32-9
32-20. Combat Tubes 32-9
32-21. Bullet-Resisting Tube 32-10
32-22. Tube Flaps 32-10
32-23. Cured-On Rubber-Covered Valve 32-10
32-24. All-Metal-Stem Cured-On Valve 32-11
32-25. Cured-In Valve 32-11
32-26. Spud-Mounted Valve 32-11
32-27. Snap-In Tubeless Tire Valve 32-12
32-28. Valve Cores 32-12
32-29. Valve Caps 32-12
32-30. Sectional Band Tracks 32-13
32-31. Double-Pin Tracks 32-14
32-32. Single-Pin Tracks 32-15

33-1. Ackerman Steering System 33-1
33-2. Fifth-Wheel Steering 33-2
33-3. Solid Axle Suspension 33-3
33-4. Center Steering Linkage 33-4
33-5. Parallelogram Steering Linkage 33-4
33-6. Rack and Pinion Steering Linkage 33-5
33-7. Worm and Sector Steering Gear 33-6
33-8. Worm and Roller Steering Gear 33-6
33-9. Cam and Lever Steering Gear 33-7
33-10. Worm and Nut Steering Gear 33-7

LIST OF ILLUSTRATIONS – CONTINUED

Figure Page

33-11. Rack and Pinion Steering Gear 33-8
33-12. Typical Power Steering Pump 33-9
33-13. Control Valve 33-10
33-14. Power Steering Gearbox 33-11
33-15. Hydraulic Cylinder 33-12
33-16. Configurations of Power Steering Systems 33-13
33-17. Air Steering 33-14
33-18. Axle End Construction for Four-Wheel Drive 33-16
33-19. Four-Wheel Steering 33-16
33-20. Steering Geometry, Illustrating Toe-Out 33-17
33-21. Caster Angle 33-18
33-22. Camber Angle 33-19
33-23. Kingpin Inclination 33-19
33-24. Toe-In 33-20
33-25. Tracking 33-21

34-1. Development of Friction and Heat 34-1
34-2. Braking Requirements 34-1
34-3. Total Vehicle Stopping Distance of an Average Vehicle 34-2
34-4. Action During Wheel Rolling and Skidding 34-3
34-5. Internal Expanding and External Contracting Brakes 34-4
34-6. Brakeshoes and Brake Lining 34-5
34-7. Brakedrum Construction 34-6
34-8. Self-Energizing and Servo Action 34-8
34-9. Drum Brake Configurations 34-9
34-10. Self-Adjusting Mechanisms 34-10
34-11. Disk Brake Assembly 34-12
34-12. Floating Caliper 34-14
34-13. Fixed Multipiston Calipers 34-15
34-14. Self-Energizing Disk Brakes 34-17
34-15. Contracting Transmission Brake 34-18
34-16. Disk Transmission Brake 34-19
34-17. Parking Brake Configurations 34-20
34-18. Mechanical Brake System 34-22
34-19. Principles of the Hydraulic System 34-24
34-20. Diagram of Hydraulic Brake System 34-25
34-21. Master Cylinder and Components 34-26
34-22. Wheel Cylinder Configurations 34-27
34-23. Brake Lines 34-28
34-24. Power Booster and Operation 34-30
34-25. Tandem-Type Booster 34-31
34-26. Piston-Type Booster 34-31
34-27. Bellows-Type Booster 34-32
34-28. Brake-Pedal Booster 34-32
34-29. Hydraulic-Power Booster 34-33
34-30. Pneumatic Principle 34-33
34-31. Typical Airbrake System 34-34
34-32. Typical Air Compressor, Two-Cylinder 34-35
34-33. Typical Air Compressor, Three-Cylinder 34-36
34-34. Governor 34-37

LIST OF ILLUSTRATIONS – CONTINUED

Figure Page

34-35. Airbrake Valve 34-37
34-36. Brake Chamber 34-38
34-37. Quick Release Valve 34-38
34-38. Relay Valve 34-39
34-39. Slack Adjuster – Partial Cutaway View 34-39
34-40. Air-Over-Hydraulic Brake System 34-40
34-41. Vacuum-Over-Hydraulic Brake System – Released 34-42
34-42. Vacuum-Over-Hydraulic Brake System – Applied 34-43
34-43. Electric Brake System 34-44

35-1. Separate Frame and Body 35-1
35-2. Integrated Frame and Body 35-2
35-3. Truck Frame (Ladder) 35-3
35-4. Typical Tank Hull 35-5
35-5. Unarmored Hulls 35-5

36-1. Winch and Power Takeoff Installation 36-1
36-2. Single-Speed, Single-Gear Power Takeoff 36-2
36-3. Single-Speed, Single-Gear Power Takeoff Installation 36-3
36-4. Auxiliary Transmission Power Takeoff Driving Winch 36-3
36-5. Typical Positions of Transfer and Power Takeoff Control Levers for Two-Speed Transfer Assembly with Power Takeoff 36-4
36-6. Jaw-Clutch Worm-Gear Winch 36-5
36-7. Location of Central Tire-Pressure Control System Components 36-6
36-8. 2 1/2-Ton 6 x 6 Gasoline Tank Truck 36-7
36-9. 2000-Gallon Tank Semitrailer 36-7
36-10. Location of Portable Pump and Hose in Tank Semitrailer 36-8
36-11. Portable Pump 36-8
36-12. Dump Truck – Side View 36-9
36-13. Dump Body – Raised 36-10
36-14. Endgate Opened for Dump 36-10
36-15. Dump Body Control Lever (Driver's Seat Removed) 36-11
36-16. Control Linkage Between Control Lever, Control Box, and Power Takeoff 36-12
36-17. Crane Assembly on Wrecking Truck 36-13
36-18. Crane A-Frame 36-13
36-19. Main Drive Chain and Associated Parts 36-14
36-20. Tank Prepared for Deepwater Fording 36-16
36-21. Ventilation System for Deepwater Fording 36-17
36-22. Crankcase Breather for Fording 36-18
36-23. Air Cleaner and Connections for Deepwater Fording 36-18

37-1. Effects of Ambient Temperature on Closed Systems 37-1
37-2. Refrigeration Cycle 37-3
37-3. Receiver and Components 37-4
37-4. Expansion Valve and Expansion Tube 37-5
37-5. Typical Evaporator 37-6
37-6. Thermostatic Switch 37-7
37-7. Hot Gas Bypass Valve 37-7
37-8. Suction Throttling Valve 37-8

LIST OF ILLUSTRATIONS – CONTINUED

Figure		Page
37-9.	Pilot-Operated Absolute (POA) Valve	37-9
37-10.	Compressor Components	37-10
37-11.	Compressor Superheat Switch	37-11
37-12.	Two-Cylinder Axial Compressor	37-12
37-13.	Four-Cylinder Radial Compressor	37-13
37-14.	Six-Cylinder Axial Compressor	37-14
37-15.	Condenser	37-15
38-1.	Typical Semitrailer Chassis	38-1
38-2.	Truck Tractor and Semitrailer Connections	38-2
38-3.	Kingpin and Plate	38-2
38-4.	Fifth Wheel	38-3
38-5.	Landing Gear	38-4
38-6.	Typical Three-Quarter Trailers	38-5
38-7.	Typical Full-Trailer Chassis	38-6
38-8.	Trailer Converter Dolly	38-7
38-9.	Tow Vehicle for Three-Quarter and Full Trailer	38-7

LIST OF TABLES

Table		Page
12-1.	Lead-Acid Vs Nickel-Cadmium Batteries	12-8
37-1.	Refrigerant-12 Pressure-Temperature Relationship	37-2

PART ONE

INTRODUCTION

CHAPTER 1

GENERAL INFORMATION

Section I. PURPOSE OF MANUAL

1-1. Usage. The manual is to be used to provide basic descriptive information to the field and to service and troop schools concerning the automotive vehicle and how it works. It also contains information that makes it a convenient reference manual. The information contained within will be of particular interest to the following:

a. Automotive maintenance personnel.

b. Maintenance supervisors.

c. Managers and supervisors responsible for interpreting automotive-related data.

d. Maintenance trainers in units and schools.

e. Individuals preparing for skill qualification tests.

1-2. Scope. This text explains the automotive vehicle in general. The explanations avoid reference to any specific vehicle or unit wherever possible. Because existing publications cover operation and maintenance of vehicles, these subjects have been omitted. The flow of power is traced from its development in the engine to its final outlet at the wheels, with the units discussed in the order in which they contribute to the power flow. Diesel and gasoline engines, except for their fuel systems, are explained together, as are radial and in-line engines. After the flow of power is traced to the wheels, those chassis components, sometimes referred to as running gear (i.e., steering system, brakes, wheels and tracks, and frames), are explained; then hulls and bodies; and finally such miscellaneous items as special equipment and trailers.

1-3. Emphasis. Wheeled vehicles have been emphasized for two reasons: first, the majority of tracked vehicles employ special adaptation with the same fundamental principles of wheeled vehicles; second, instruction will be facilitated by the reference to wheeled vehicles because most parts are more accessible and more visible than on tracked vehicles. Again, to aid instruction, the military vehicle has been correlated with commercial vehicles that may be familiar to the student.

Section II. ORGANIZATION OF THE MANUAL

1-4. General. Many different methods are used to group vehicle units and assemblies. The method employed in this text has been chosen because it more readily lends itself to a logical and simplified development of the material to be presented.

1-5. Engine. The basic engine (gasoline, diesel, and gas turbine) is discussed later in the manual with all of its supporting systems, such as cooling, lubrication, ignition, fuel, and exhaust.

1-6. Electrical System and Related Units. The electrical system includes all lighting systems and electrically operated accessory systems.

1-7. Power Train. The power train includes all components and systems that are used to get the power from the engine to the driving wheels.

1-8. Chassis Components. The chassis components (also known as running gear) include the suspension, brakes, steering, wheels, tires, and tracks.

1-9. Bodies, Hulls, and Frames. Bodies, frames, and hulls include the various body frame configurations, hull designs, trailer configurations, truck body configurations, and accessory systems (including refrigeration).

xxu

1-10. Terminology. The terminology part of the manual will describe those terms used in the text that pertain to automotive technology or describe military vehicle characteristics.

Section III. HISTORY OF MILITARY VEHICLES

1-11. Pre-World War II. In 1912, four commercial trucks were purchased by the US Army for experimental purposes. Thus, motor vehicles were introduced as a means of transporting military personnel, supplies, and equipment. By 1916, when a punitive expedition was sent against the Mexican bandits, interest had been stimulated to the point that a nonstandard fleet of trucks was assembled at the Mexican border and used in the campaign. At that time, it was discovered that commercial transportation did not meet military requirements on operations over rough terrain or in the vital requirements of maintenance and repair. This discovery brought about the standardized designs of operating equipment and a variety of modifications to meet military requirements. As a result, a majority of the thousands of vehicles used in World War I were standardized and possessed a moderate degree of interchangeability. Trench warfare caused the development of an automotive vehicle used only for combat purposes; thus the tank was developed. American design and experimentation were carried on in the period between the two World Wars to develop a fleet of military wheeled vehicles that were entirely standardized and had a high degree of interchangeability. Under the program, industry began to produce vehicles with both front- and rear-wheel drives, a feature required of a military vehicle for successful operation over any terrain but found only in special commercial equipment. After German tanks and combat vehicles proved so successful against the Polish, French, and British armies in 1939 and 1940, American tank development was increased. The United States equaled, and in some instances surpassed, the Axis powers in the race to develop superior combat vehicles and was able to use overwhelming quantities of automotive materiel against them to help bring about their defeat.

1-12. Post-World War II. Since World War II, the United States has continually pressed its research and development program for more and better vehicles. Foreign commitments have forced the United States to rapidly update its military equipment to meet particular countries' soil and climatic conditions, including adapting to temperatures from −70°F (-57°C) to +125°F (+52°C), rough and hilly terrain, sand, mud, snow, and swamps. It is difficult to visualize the many and varied requirements that must be incorporated in each tactical and combat vehicle, whether it be wheeled or tracked. The development of our military vehicles is parallel with the history of our country. Sudden involvement usually results in crash programs to revise and modify existing materiel; however, during peacetime and when the time element is not critical, the trend is toward a partial or completely new concept of a vehicle (or system) for a designated purpose. Whatever the case may be, certain elements must be taken into consideration. One is product improvement, which usually comes about by a gradual change, with the modification of a single component, whether it be a bolt or a gear in a transmission. Closely associated with this is reliability, the ability to meet certain requirements as specified with a minimum of maintenance. Many tactical requirements of military vehicles are closely related, and to meet these ends, families of vehicles have dominated the scene. Generally speaking, this means a specific chassis and power train, with or without modification, is used with added equipment to produce a cargo truck, wrecker, or tank truck. In addition to satisfying these requirements, a high degree of interchangeability of repair parts is achieved. This is one form of standardization of designs. Additional aspects that must be considered for development of today's vehicles include newer techniques in maintenance, the introduction of advanced metals for lightweight construction, air transportability, and capability to ford a body of water.

Section IV. CHARACTERISTICS OF MILITARY VEHICLES

1-13. General. Military vehicles incorporate all forms of wheeled and tracked vehicles including the full range of body types found in commercial vehicles. However, there are also bodies and equipment that are unique to military operations. They include all types of trucks, tractors, truck tractors, personnel carriers, tanks, self-propelled guns, motorized and mechanized special purpose equipment, trailers, vans, and special purpose towed vehicles.

The principal distinction between these vehicles and their commercial counterparts is that military vehicles are specifically designed for military purposes. This includes combat operations and the transportation of cargo, personnel, or equipment; towing other vehicles or equipment; and operations, both cross country and over roads, in close support of combat vehicles and troops. They are designed and constructed to endure the rigors of the military environment and to continue to operate at, or above, a prescribed minimum performance level in this environment. They have excellent cross-country performance capabilities over all types of terrain where tactical or combat operations can be conducted. This includes snow and ice, rocky terrain, swamps, and desert sands. In order to negotiate water barriers with a minimum of preparation, all sensitive equipment is either permanently waterproofed to prevent damage by immersion, or designed to function underwater.

1-14. Features. Some of the features and characteristics that are standard on military vehicles are:

a. 24-volt, fully waterproofed, fungus-proofed electrical systems that are fully suppressed to prevent interference to electronic equipment.

b. Engines capable of operating while fully submerged in either freshwater or seawater.

c. Oversized air, oil, and fuel filtering capacities.

d. Oversized generator capacity.

e. Oversized engine oil and cooling capacities.

f. Engines that are less critical of the fuel they require and have a lower specific weight (pound per horsepower).

g. Reliability over an extremely wide temperature range.

h. Provisions for operating during blackout conditions.

i. All-wheel drive on wheeled vehicles.

j. Improved ease of servicing and maintenance.

Section V. MILITARY VEHICLE CATEGORIES

1-15. Administrative Vehicles. Administrative vehicles comprise the standard commercially available vehicles commonly used at camps, posts, stations, and various US Government installations for routine administrative duties. These vehicles have a minimum of modifications to adapt them to military service. In some instances, no modification whatsoever is made.

1-16. Tactical Vehicles. Tactical vehicles generally are defined as vehicles that have been designed and manufactured specifically to meet the severe requirements imposed by combat and tactical operations in the field. Whereas combat vehicles are defined as vehicles designed to perform specific functions in combat, tactical vehicles are designed specifically to support the tactical play of the operation. Military tactics is that branch of the military that deals with the arranging, positioning, and maneuvering of the forces in or near contact with the enemy; also, the maneuvering and positioning of materiel and supplies in support of the forces in contact. Because the main purpose of tactical vehicles is to give direct support to the combat vehicles, they are required to have the same high quality of mobility as do combat vehicles; and like combat vehicles, they are designed to exacting military characteristics to survive and perform satisfactorily in the military environment. The majority of wheeled vehicles fall into the tactical rather than the combat vehicle category.

1-17. Combat Vehicles. Combat vehicles are defined as land or amphibious vehicles, with or without armor or armament, designed for specific functions in combat or battle. The later installation of armor or armament onto other than combat vehicles does not alter their original classification. They may be wheeled or tracked but in all cases they are designed to have a high degree of mobility in off-road operations. Some typical

xx611

combat vehicles are tanks, self-propelled artillery, missile launchers, and armored cars. The majority of combat vehicles at the present time are tracked vehicles, but this is not a requirement of this classification. Due to their missions, combat vehicles usually are equipped with both armor and armament; however, certain antitank vehicles are unarmored and depend upon their decreased silhouette and increased speed and maneuverability for protection. A continuing demand for greater firepower and mobility has resulted in an increasing use of lightweight armor on vehicle bodies and hulls. The reduction in vehicle weight enables some vehicles that would otherwise be too heavy to take part in airborne operations; it also improves their amphibious capabilities. Weight reduction in the newer types of combat vehicles is largely due to extensive use of aluminum in their construction, including aluminum armor.

Section VI. CLASSIFICATION OF VEHICLES

1-18. General. The term vehicle, as used in the Army, includes all wheeled and tracked equipment, all chassis powered by a self-contained power unit, and trailers and semitrailers towed by vehicles. (See para 1-13 for characteristics.)

1-19. Classification According to Design.

a. General Transport Vehicles. General transport vehicles are motor vehicles designed to be used interchangeably for movement of personnel and cargo and used to satisfy general automotive transport needs without modification to the chassis. The 2 1/2-ton, 6 x 6 cargo truck is an example of a general transport vehicle.

b. Special Equipment Vehicles. Special equipment vehicles are general transport vehicles that have had some minor modifications such as a special body or special equipment mounted thereon. The ordnance shop truck (ordnance maintenance truck, 2 1/2-ton, 6 x 6) is in this class because a special body to house shop equipment has been mounted on the chassis of a general transport vehicle, 2 1/2-ton, 6 x 6.

c. Special Purpose Vehicles. Special purpose vehicles are motor vehicles designed and intended for a specialized requirement for which no general transport vehicle chassis can be adapted. This category includes items that are specified from time to time by agencies other than the Army Materiel Command. That agency, however, retains the responsibility for the basic components of the vehicle. All tractors, regardless of size or intended purpose, are classified as special purpose vehicles.

d. Trailers. Trailers are vehicles designed to be towed and are provided with a drawbar or tongue for attachment to a coupling mounted on the towing vehicle.

e. Semitrailers. Semitrailers are vehicles designed to be towed and are supported in part by a prime mover (towing vehicle) through a fifth wheel or similar coupling.

1-20. Classification by Ground Contact. Under this general classification, vehicles may be further subclassified into wheeled and tracked vehicles.

a. Wheeled vehicles may be classified by the number of wheels and the number of driving wheels. Where such data as 4 x 4, 6 x 6, 8 x 8, etc, appear in vehicular nomenclature, the first figure indicates total number of wheels and the second figure indicates number of driving wheels.

Vehicle has four wheels ← 4 x 4 → Vehicle has four driving wheels

It should be noted that all six-wheel vehicles have three axles; that is, wheels are considered a unit whether they are single (one tire) or dual (two tires).

b. Tracked vehicles are so called because the tracks serve the purpose of providing a supporting platform of relatively large area under the road or suspension wheels of the vehicles.

PART TWO

ENGINES

CHAPTER 2

PISTON ENGINE CHARACTERISTICS

Section I. ENGINE OPERATION

2-1. Introduction.

a. Because the most widely used piston engine is the four-stroke cycle type, it will be used as the example for section I, Engine Operation and as the basis for comparison in section II, Comparison of Engine Types.

b. The operation of the piston engine can best be understood by comparing it to a simple cannon. In A, figure 2-1 a cannon barrel, charge of gunpowder, and a cannonball are illustrated. In B, figure 2-1 the gunpowder is ignited. The gunpowder burns very rapidly and as it burns there is a rapid expansion of the resulting gases. This rapid expansion causes a tremendous increase in pressure that forces the cannonball from the barrel.

In A, figure 2-2 the cannon barrel has been replaced by a cylinder and a combustion chamber. The cannonball has been replaced by a piston. A mixture of vaporized fuel and air has replaced the gunpowder. In B, figure 2-2 the gasoline is ignited. This time, the resulting force acts to push the piston downward.

2-2. Reciprocating Motion to Rotary Motion. The force of the piston acting in a downward motion is of little value if it is to turn the wheels of the vehicle. In order to utilize this straight line or reciprocating motion, it must be transformed into rotary motion. This is made possible through the use of a crankshaft. The crankshaft, as the name implies, is a shaft connected to the driving wheels of a vehicle through the drive train on one end. On the other end of the shaft is a crank with a crankpin offset from the shaft's center. Figure 2-3 illustrates how the piston and the crankshaft are connected through the connecting rod and the crankpin.

Figure 2-4 illustrates how reciprocating motion of the piston is changed to rotating motion of the crankshaft.

2-3. Intake and Exhaust. If the engine is going to operate, the fuel and air mixture must be fed into the combustion chamber. The burnt gases also must be exhausted after the fuel is burned. To accomplish this, there is a passage to the combustion chamber called the intake port and a passage from the combustion chamber to the exhaust

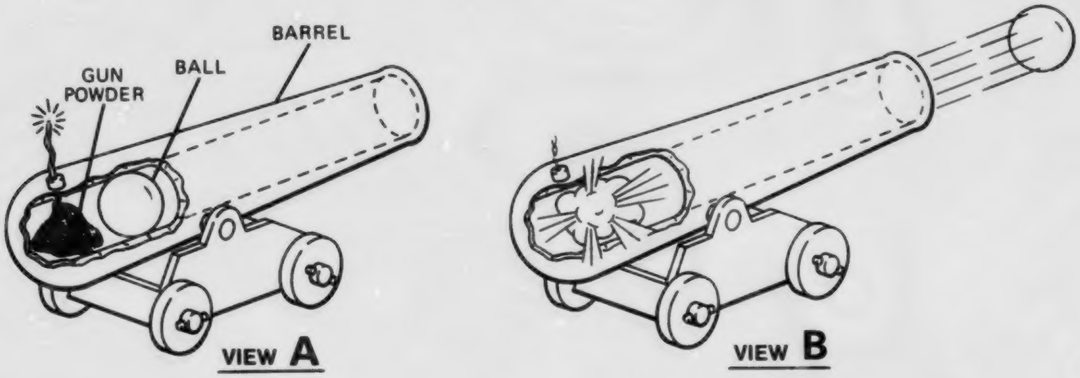


Figure 2-1. Piston Engine Principles.

TA233309

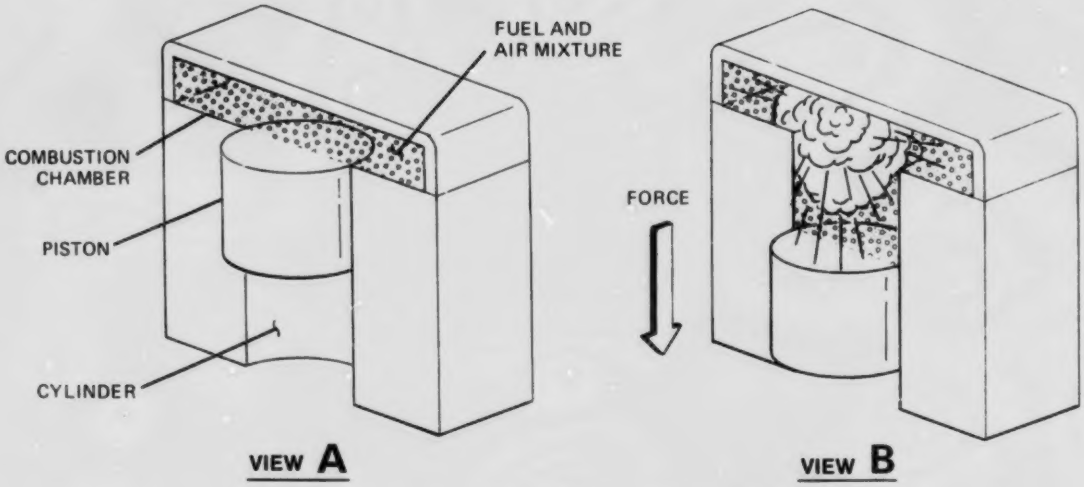


Figure 2-2. Piston Engine Operation.

system called the exhaust port. A simplified arrangement is shown in figure 2-5.

By putting openings in the combustion chamber, another problem is created. The problem is that the force of the burning fuel and air mixture will be lost through these openings rather than pushing down the piston. To solve this problem, there must be something that opens and closes the intake and exhaust ports to the combustion chambers. To accomplish this, a valve is added to each of these ports and these valves are called the intake and exhaust valves. A simplified arrangement is shown in figure 2-6.

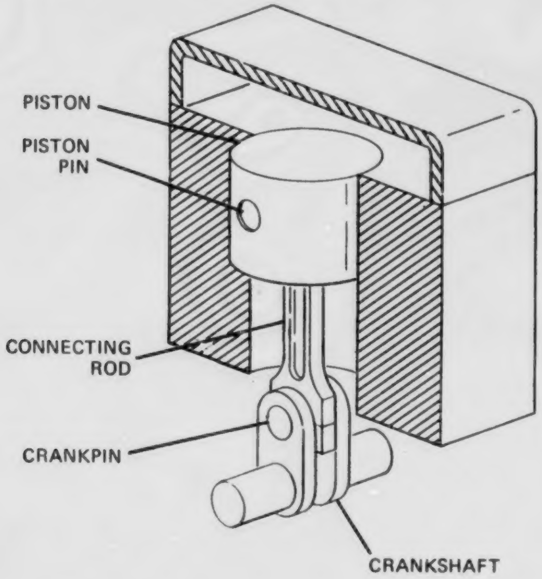


Figure 2-3. Piston and Crankshaft.

The intake and the exhaust valves are opened and closed in a timed sequence by the valve train. The valve train will be discussed in paragraph 2-9.

2-4. Action in the Cylinder. When the piston is at its highest point in the cylinder, it is in a position called top dead center (tdc). When the piston is at its lowest point in the cylinder, it is in a position called bottom dead center (bdc). As the piston moves from top dead center to bottom dead center or vice versa, the crankshaft rotates exactly one-half of a revolution, as shown in figure 2-7.

Each time the piston moves from top dead center to bottom dead center, or vice versa, it completes a movement called a stroke. Therefore, the piston completes two strokes for every full crankshaft revolution. There are four definite phases of operation that an engine goes through in one complete operating cycle. Each one of these operating phases is completed in one piston stroke. Because of this, each operating phase is also referred to as a stroke. Because there are four strokes of operation, the engine is referred to as a four-stroke cycle engine. The four strokes are intake, compression, power, and exhaust. Because there are four strokes in one operating cycle, it may be concluded that there are two complete crankshaft revolutions in each operating cycle.

TA233310

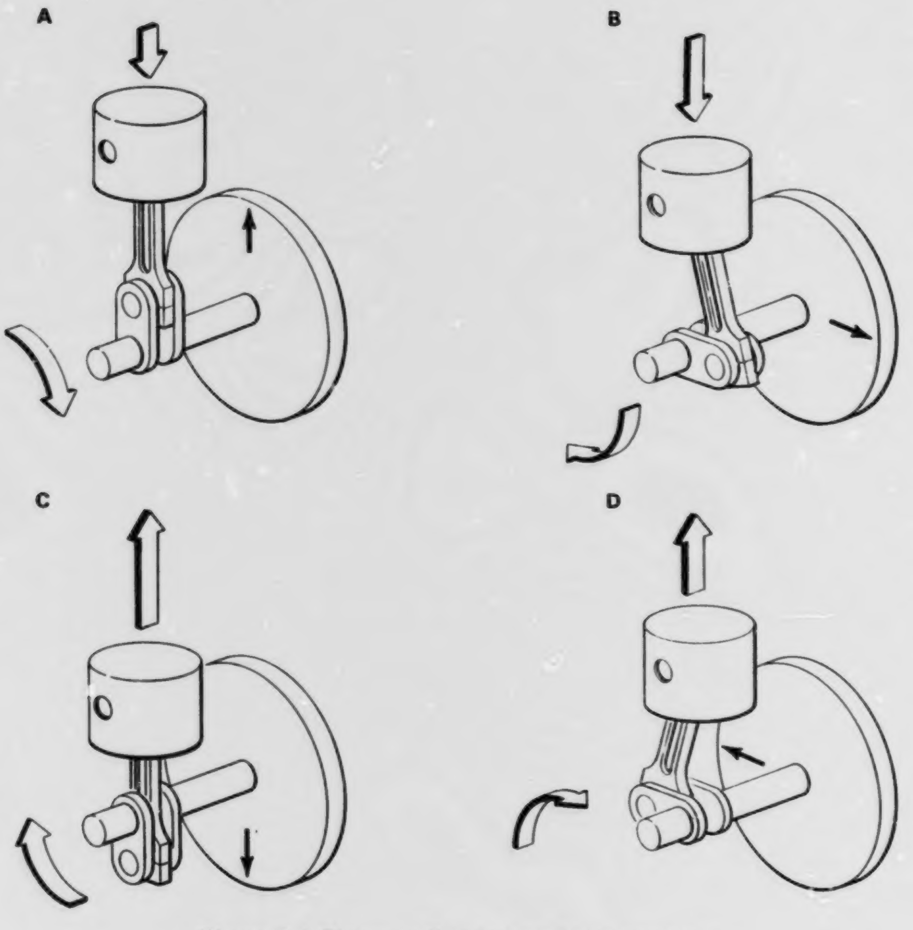


Figure 2-4. Piston to Crankshaft Relationship.

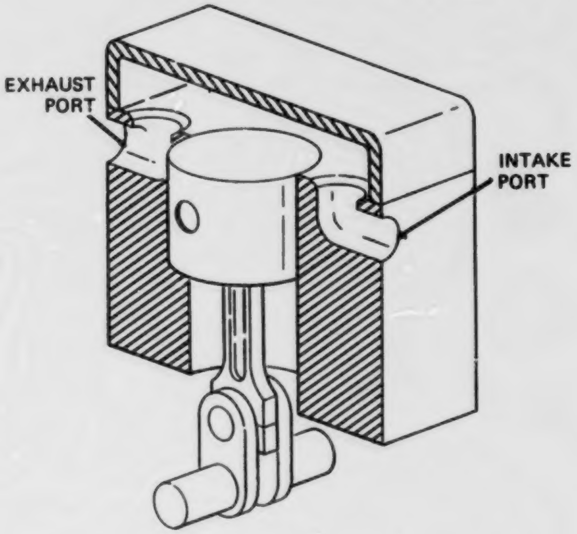

EXHAUST PORT
INTAKE PORT

Figure 2-5. Intake and Exhaust Ports.

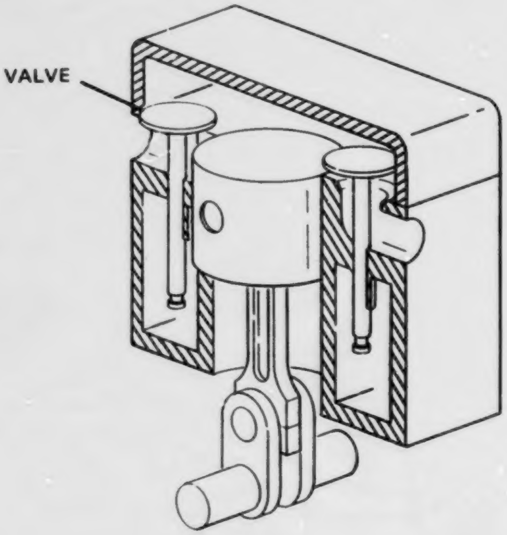
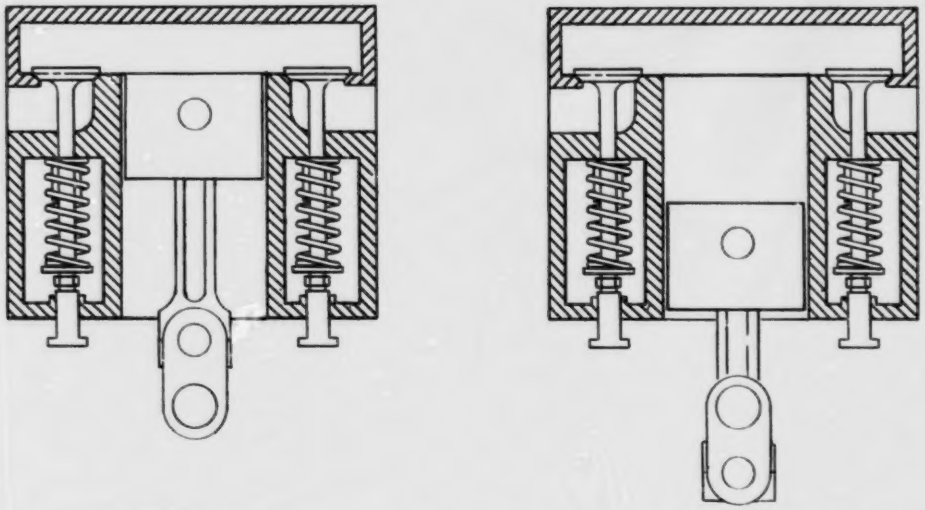


Figure 2-6. Intake and Exhaust Valves.

TA233311



PISTON AT TOP DEAD CENTER

PISTON AT BOTTOM DEAD CENTER

Figure 2-7. Piston Positions.

2-5. Intake Stroke (A, Fig. 2-8). The intake stroke begins at top dead center. As the piston moves down, the intake valve opens. The downward movement of the piston creates a vacuum in the cylinder. The vacuum causes a fuel and air mixture to be drawn through the intake port into the combustion chamber. As the piston reaches bottom dead center, the intake valve closes.

2-6. Compression Stroke (B, Fig. 2-8). The compression stroke begins with the piston at bottom dead center. Both the intake and the exhaust valves remain closed. As the piston moves toward top dead center, the amount of space in the upper cylinder gets smaller. The fuel and air mixture is compressed and the potential energy in the fuel is concentrated. The compression stroke ends when the piston reaches top dead center.

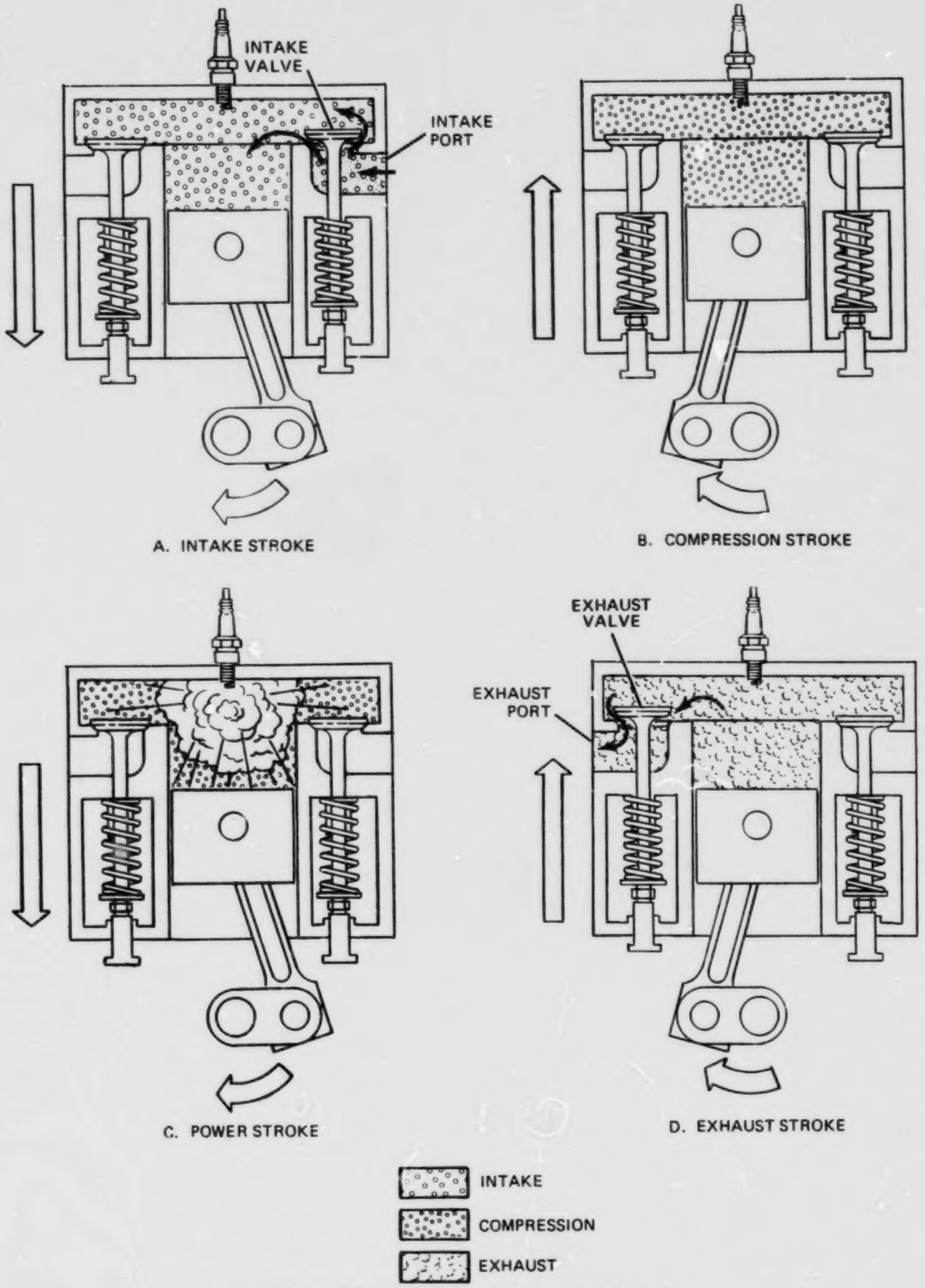
2-7. Power Stroke (C, Fig. 2-8). As the piston reaches top dead center, ending the compression stroke, the spark plug (para 15-3) ignites the compressed fuel and air mixture. Because both valves are closed, the force of the resulting explosion pushes the piston down, giving a powerful driving thrust to the crankshaft. The power stroke ends as the piston reaches bottom dead center.

2-8. Exhaust Stroke (D, Fig. 2-8). As the piston reaches bottom dead center, ending the compression stroke, the exhaust valve opens, beginning the exhaust stroke. As the piston moves upward toward top dead center, it pushes the burnt gases from the fuel and air mixture out of the combustion chamber through the exhaust port. As the piston reaches top dead center, ending the exhaust stroke, the exhaust valve closes. As the exhaust valve closes, the intake valve opens to begin the intake stroke in the next cycle.

2-9. Valve Train. It is obvious in paragraphs 2-5 thru 2-8 that it is very important to operate the valves in a timed sequence. If the exhaust valve opened in the middle of the intake stroke, the piston would draw burnt gases into the combustion chamber with a fresh mixture of fuel and air. As the piston continued to the power stroke, there would be nothing in the combustion chamber that would burn. The engine is fitted with a valve train to operate the valves.

A simplified valve train is illustrated in A, figure 2-9. The camshaft is made to rotate with the crankshaft through the timing gears. The raised piece on the camshaft is called a cam lobe. As illustrated in view B, the valve spring is designed to hold the valve closed.

The cam lobe contacts the bottom of the lifter as it rotates with the camshaft, as shown in view C. As


INTAKE VALVE
INTAKE PORT
EXHAUST VALVE
EXHAUST PORT
INTAKE
COMPRESSION
EXHAUST

A. INTAKE STROKE

B. COMPRESSION STROKE

C. POWER STROKE

D. EXHAUST STROKE

Figure 2-8. Four-Stroke Cycle Operation.

TA233313

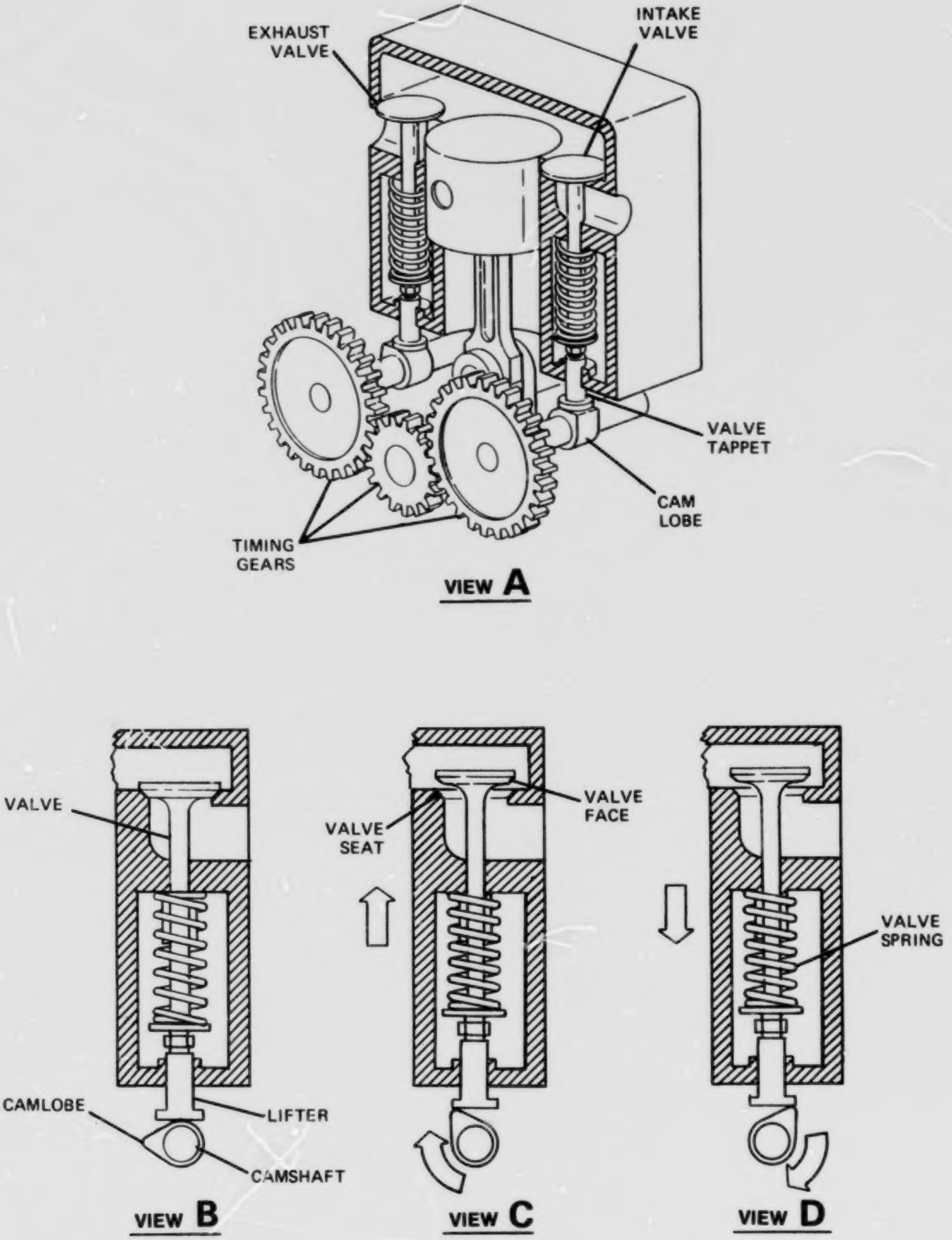

EXHAUST VALVE
INTAKE VALVE
VALVE TAPPET
CAM LOBE
TIMING GEARS
VIEW A
VALVE
VALVE SEAT
VALVE FACE
VALVE SPRING
CAMLOBE
LIFTER
CAMSHAFT
VIEW B
VIEW C
VIEW D

Figure 2-9. Valve Train Operation.

TA233314

the cam lobe pushes up on the lifter, it will in turn push the valve open against the pressure of the spring. In view D, the cam lobe has passed the center of the lifter bottom. As it rotates away from the lifter, the valve spring pulls the valve closed.

By proper positioning of the cam lobes on the camshaft, a sequence can be established for the intake and exhaust valves. It is demonstrated in paragraphs 2-5 thru 2-8 that the intake valve and the exhaust valve must each open once for every operating cycle. As explained in paragraph 2-4, the crankshaft must make two complete revolutions to complete one operating cycle. Using these two facts, a camshaft speed must be exactly one-half the speed of the crankshaft. To accomplish this, the timing gears are made so that the crankshaft gear has exactly one-half as many teeth as the camshaft gear, as shown in figure 2-10. The timing marks are used to put the camshaft and the crankshaft in the proper position to each other.

2-10. Engine Accessory Systems.

a. Fuel System. The fuel system (chapter 4) supplies the engine with a properly proportioned fuel and air mixture. It also regulates the amount of the mixture to the engine to control engine speed and power output.

b. Ignition System. The ignition system (chapter 15) ignites the fuel and air mixture in the combustion chamber at the precise moment needed to make the engine run.

c. Cooling System. The cooling system (chapter 9) removes the excess heat from the engine that is generated from combustion.

d. Lubrication System. The lubrication system (chapter 8) provides a constant supply of oil to the engine to lubricate and cool the moving parts.

e. Flywheel (Fig. 2-11). As discussed in paragraphs 2-5 thru 2-8, for every two revolutions that the crankshaft makes, it only receives one power stroke lasting for only one-half of one revolution of the crankshaft. This means that the engine must coast through one and one-half crankshaft revolutions in every operating cycle. This would cause the engine to produce very erratic power output. To solve this problem, a flywheel is added to the end of the crankshaft. The flywheel, which is very heavy, will absorb the violent thrust of the power stroke. It will then release the energy back to the crankshaft so that the engine will run smoothly.

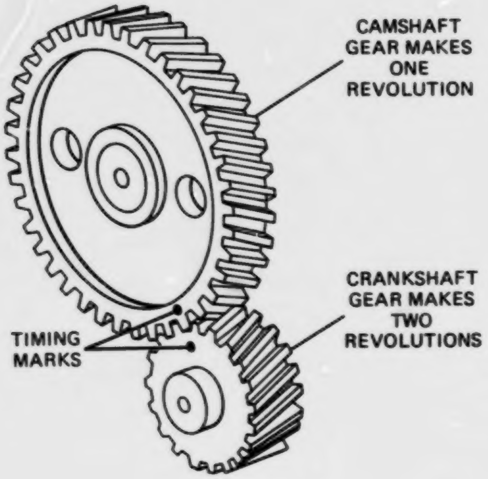

CAMSHAFT GEAR MAKES ONE REVOLUTION
CRANKSHAFT GEAR MAKES TWO REVOLUTIONS
TIMING MARKS

Figure 2-10. Timing Gears.

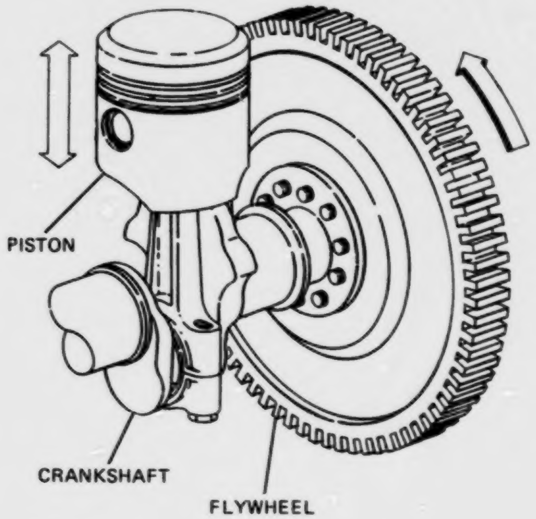


Figure 2-11. Flywheel.

TA233315

BEST COPY AVAILABLE

Section II. COMPARISON OF ENGINE TYPES

2-11. Internal Combustion Engine Versus External Combustion Engine.

a. Internal Combustion Engine (A, Fig. 2-12). An internal combustion engine is any engine in which the fuel is burned within it. A four-stroke cycle engine is an internal combustion engine because the combustion chamber is located within the engine as shown in figure 2-12.

b. External Combustion Engine (B, Fig. 2-12). An external combustion engine is an engine in which the fuel is burned outside of the engine. A steam engine is a perfect example. The fuel is burned in an outside boiler, where it makes steam. The steam is piped to the engine to make it run.

2-12. Four-Stroke Cycle Versus Two-Stroke Cycle. The engine described in section I is a four-stroke cycle engine. There is another form of gasoline piston engine that has no valve mechanisms and completes one operating cycle for every revolution of the crankshaft. It is called a two-stroke cycle engine and is illustrated in figure 2-13. Instead of placing intake and exhaust ports in the combustion chamber, they are placed in the cylinder wall. In this engine, the piston goes through a power stroke every time it moves from top dead center to bottom dead center. The

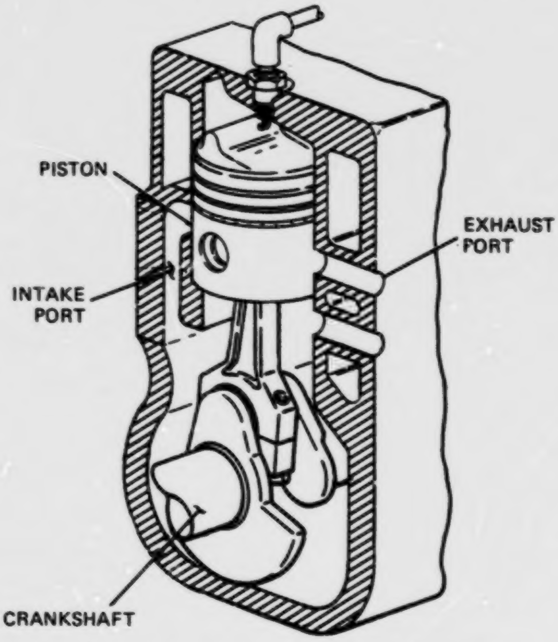

PISTON
EXHAUST PORT
INTAKE PORT
CRANKSHAFT

Figure 2-13. Two-Stroke Cycle Engine.

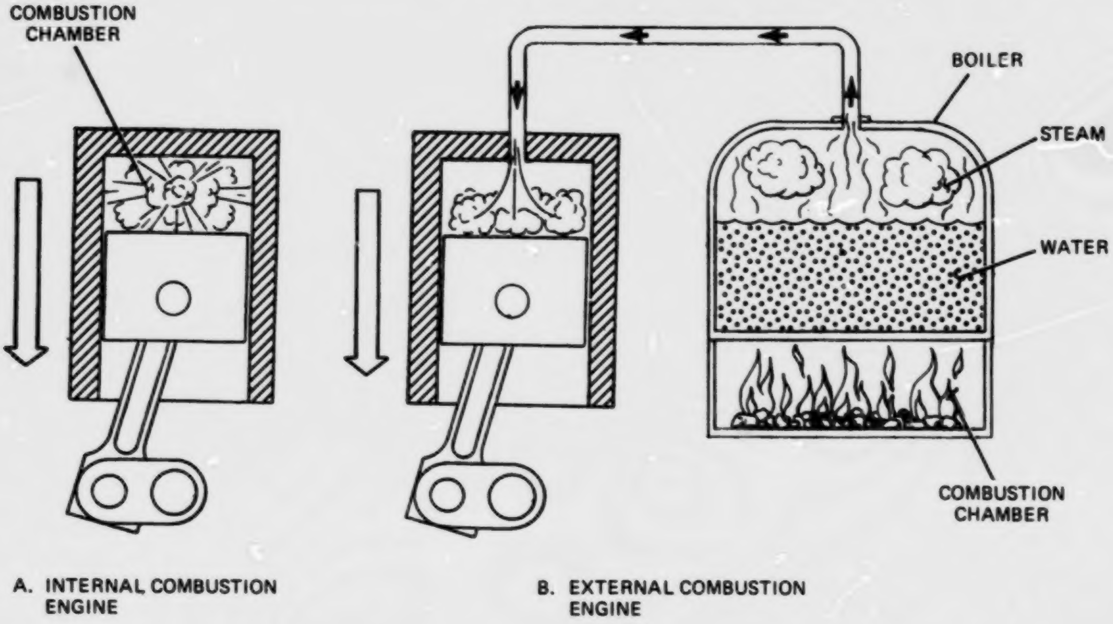

COMBUSTION CHAMBER
BOILER
STEAM
WATER
COMBUSTION CHAMBER
A. INTERNAL COMBUSTION ENGINE
B. EXTERNAL COMBUSTION ENGINE

Figure 2-12. Internal Combustion Engine Versus External Combustion Engine.

TA233316

BEST COPY AVAILABLE

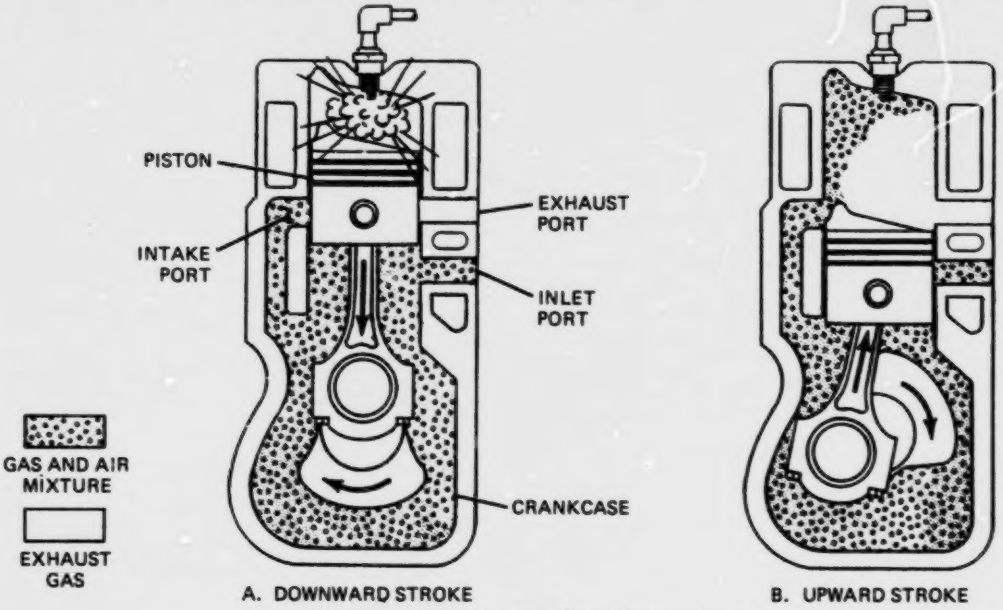
downward stroke is also an intake and an exhaust stroke. As the piston moves from bottom dead center back to top dead center, it is going through a compression stroke.

a. Downward Stroke (A, Fig. 2-14). The piston begins the power stroke at top dead center. As the exploding fuel and air mixture pushes the piston downward, it first covers the inlet port. This seals the crankcase. As the piston continues downward,it pressurizes the sealed crankcase, which contains a vaporized fuel and air mixture. As the piston continues to bottom dead center, it uncovers the intake and the exhaust ports. The pressure built up in the crankcase forces the fuel and air mixture into the cylinder through the intake port. The top of the piston is shaped to divert the mixture upward and away from the exhaust port. As the mixture enters the cylinder, it displaces and pushes the burnt gases out through the exhaust port.

b. Upward Stroke (B, Fig. 2-14). As the piston moves upward, it covers the intake and exhaust ports. This seals the upper cylinder so that the upward movement of the piston compresses the fuel and air mixture. At the same time, the upward movement of the piston creates a suction in the crankcase so that as the inlet port is uncovered, a mixture of fuel and air is drawn into the crankcase. As the piston reaches top dead center, the spark plug ignites the fuel and air mixture, beginning the downward power stroke again.

c. The Fuel and Lubrication System. The fuel and air mixture must first pass through the crankcase before it gets to the combustion chamber. For this reason, the fuel and air mixture must also provide lubrication for the rotating and reciprocating parts. This is accomplished by mixing a small percentage of oil with the fuel. The oil, mixed with the fuel and air mixture, enters the crankcase in a vapor that constantly coats the moving parts.

d. Power Output. It may seem like a two-stroke cycle engine will put out twice as much power as a comparable four-stroke cycle engine because there are twice as many power strokes. However, this is not the case. Because the force of the fuel and air mixture entering the cylinder must be relied upon to get rid of the burnt gases in the cylinder from the last power stroke, there is a certain amount of dilution of it. The mixing of the intake mixture with exhaust gases reduces its potential power output. Also, with the inlet and exhaust ports opened together, a certain amount of the fuel and air mixture is lost. There is also a much shorter period that the inlet port is open. This reduces the amount of power from each power stroke.



A. DOWNWARD STROKE

B. UPWARD STROKE

Figure 2-14. The Two-Stroke Cycle.

TA233317

e. Advantage and Usage. The two-stroke cycle engine is used almost exclusively in very small equipment. It is lightweight and able to run at very high speeds due to the absence of a mechanical valve train.

2-13. Gasoline Engine Versus Diesel Engine.

a. General. In many respects, the four-stroke cycle gasoline engine and the four-stroke cycle diesel engine are very similar. They both follow an operating cycle that consists of intake, compression, power, and exhaust strokes. They also share in the same system for intake and exhaust valves. The component parts of a diesel engine are shown in figure 2-15. The main differences between gasoline engines and diesel engines follow.

(1) The fuel and air mixture is ignited by the heat generated by the compression stroke in a diesel engine versus the use of a spark ignition system on a gasoline engine. The diesel engine needs no ignition system. For this reason, the gasoline engine is referred to as a spark ignition engine and a diesel engine is referred to as a compression ignition engine.

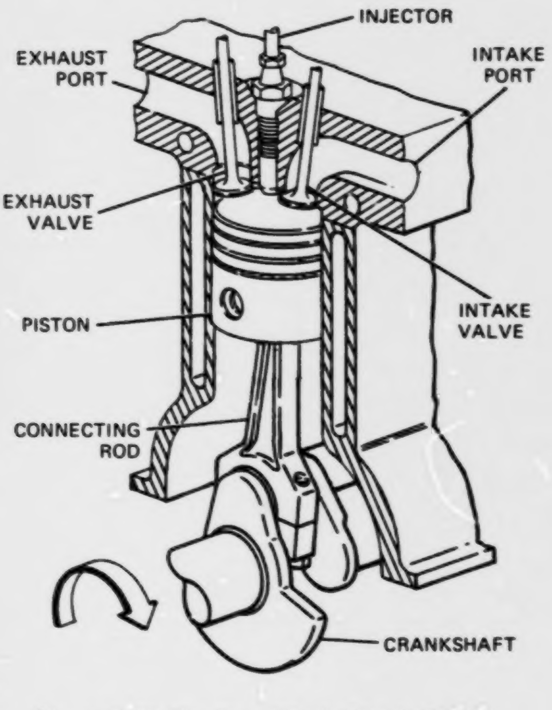


Figure 2-15. The Four-Stroke Cycle Diesel.

(2) The fuel and air mixture is compressed to about one-twentieth of its original volume in a diesel engine. In contrast, the fuel and air mixture in a gasoline engine is compressed to about one-eighth of its original volume. The diesel engine must compress the mixture this tightly to generate enough heat to ignite the fuel and air mixture. The contrast between the two engines is shown in figure 2-16.

(3) The gasoline engine mixes the fuel and air before it reaches the combustion chamber. A diesel engine takes in only air through the intake port. Fuel is put into the combustion chamber directly through an injection system. The air and fuel then mix in the combustion chamber. This is illustrated in figure 2-17.

(4) The engine speed and the power output of a diesel engine are controlled by the quantity of fuel admitted to the combustion chamber. The amount of air is constant. This contrasts with the gasoline engine where the speed and power output are regulated by limiting the air entering the engine. This is illustrated in figure 2-18.

b. Operation.

(1) *Intake (A, Fig. 2-19).* The piston is at top dead center at the beginning of the intake stroke. As the piston moves downward, the intake valve opens. The downward movement of the piston draws air into the cylinder. As the piston reaches bottom dead center, the intake valve closes. The intake stroke ends here.

(2) *Compression (B, Fig. 2-19).* The piston is at bottom dead center at the beginning of the compression stroke. The piston moves upward, compressing the air. As the piston reaches top dead center, the compression stroke ends.

(3) *Power (C, Fig. 2-19).* The piston begins the power stroke at top dead center. Air is compressed in the upper cylinder at this time to as much as 500 psi (3448 kPa). The tremendous pressure in the upper cylinder brings the temperature of the compressed air to approximately 1000°F (538°C). The power stroke begins with the injection of a fuel charge into the engine. The heat of compression ignites the fuel as it is injected. The expanding force of the burning gases pushes the piston downward, providing power to the crankshaft. The power generated in a

TA233318

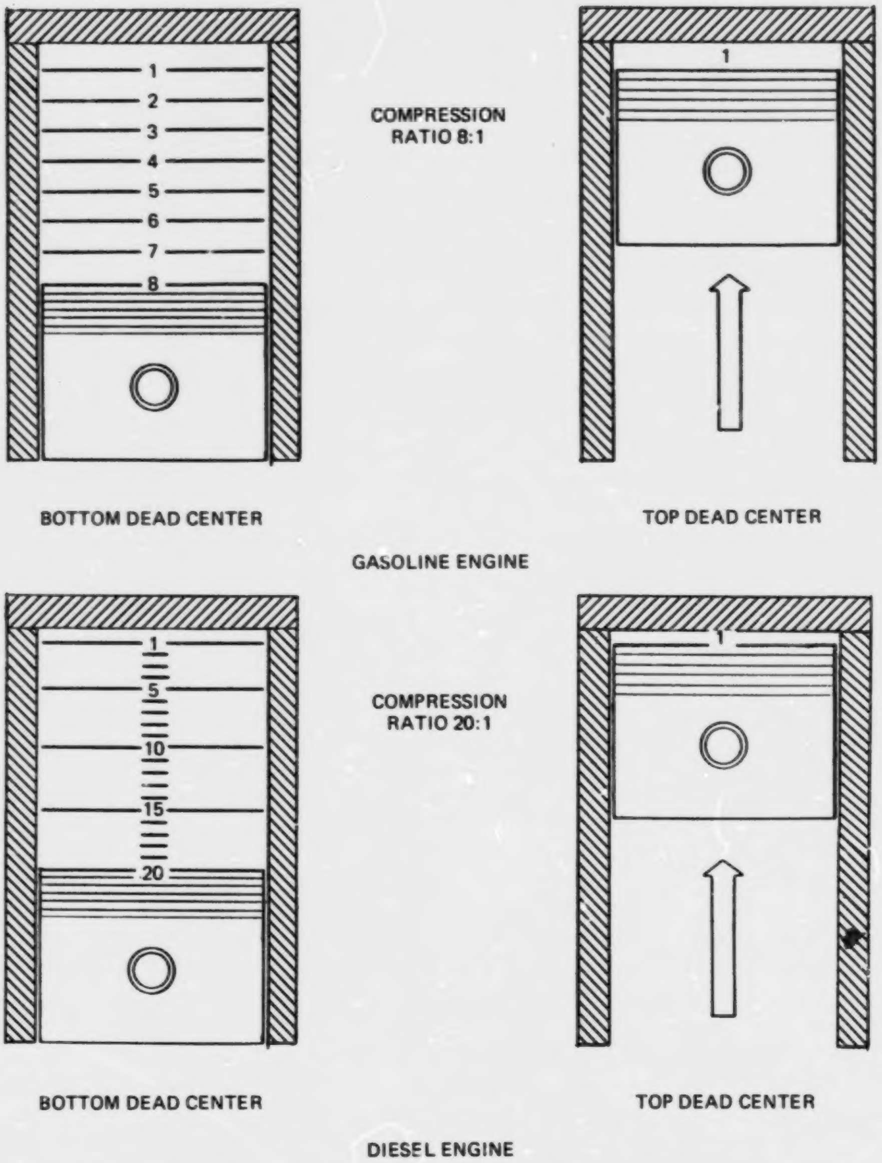

1
2
3
4
5
6
7
8
1
COMPRESSION RATIO 8:1
BOTTOM DEAD CENTER
TOP DEAD CENTER
GASOLINE ENGINE
1
5
10
15
20
1
COMPRESSION RATIO 20:1
BOTTOM DEAD CENTER
TOP DEAD CENTER
DIESEL ENGINE

Figure 2-16. Comparison of Diesel and Gasoline Engine Compression Strokes.

diesel engine is continuous throughout the power stroke. This contrasts with a gasoline engine, which has a power stroke with rapid combustion in the beginning and little or no combustion at the end.

(4) *Exhaust (D, Fig. 2-19).* As the piston reaches bottom dead center on the power stroke, the power stroke ends and the exhaust stroke begins. The exhaust valve opens and the piston pushes the burnt gases out through the exhaust port. As the piston reaches top dead center, the exhaust valve closes and the intake valve opens. The engine is now ready to begin another operating cycle.

c. Advantages.

(1) The diesel engine is much more efficient than a gasoline engine. This is due to the much tighter compression of the fuel and air mixture. The diesel engine produces tremendous

TA233319

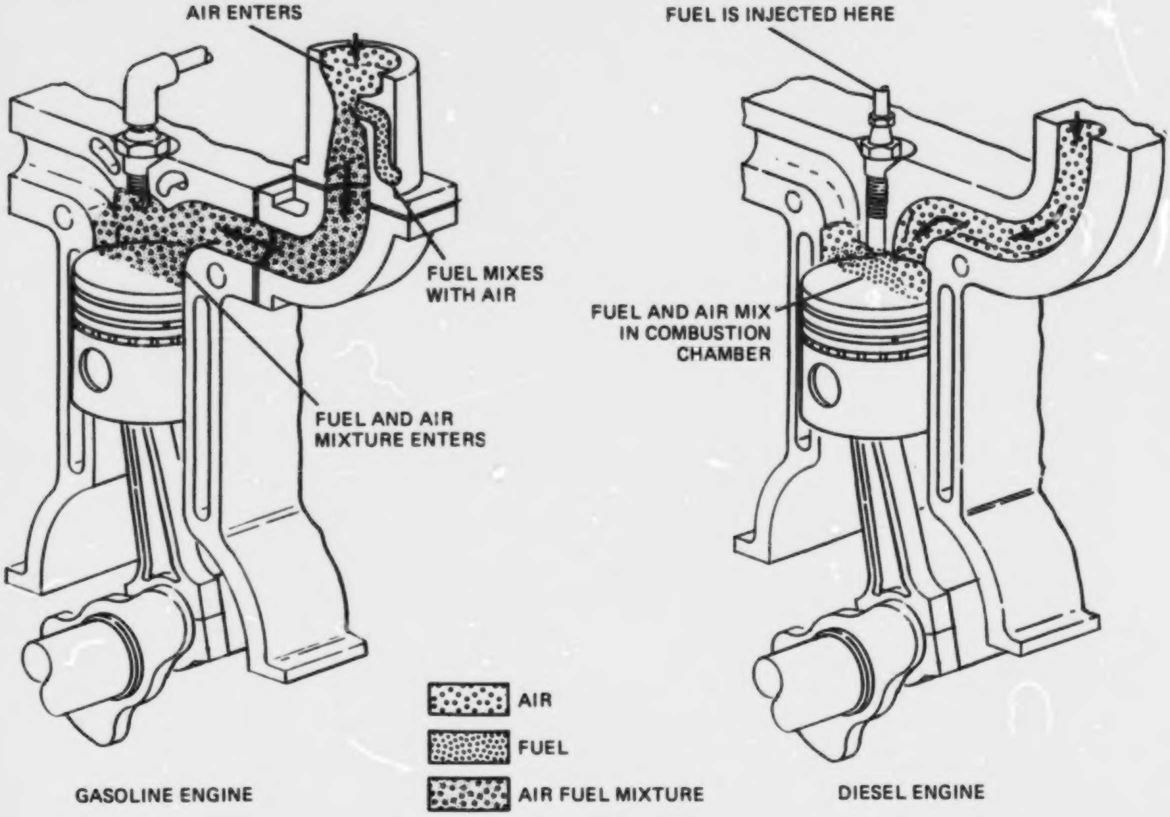

AIR ENTERS
FUEL MIXES WITH AIR
FUEL AND AIR MIXTURE ENTERS
GASOLINE ENGINE
FUEL IS INJECTED HERE
FUEL AND AIR MIX IN COMBUSTION CHAMBER
DIESEL ENGINE
AIR
FUEL
AIR FUEL MIXTURE

Figure 2-17. Comparison of Diesel and Gasoline Engine Intake Strokes.

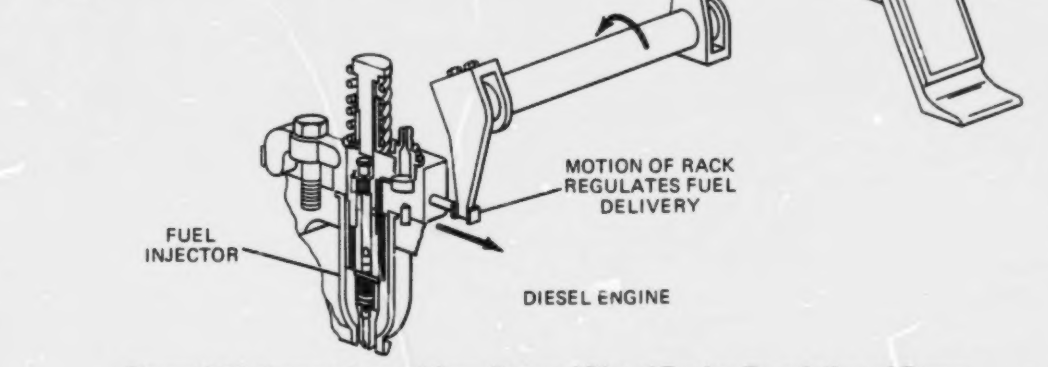
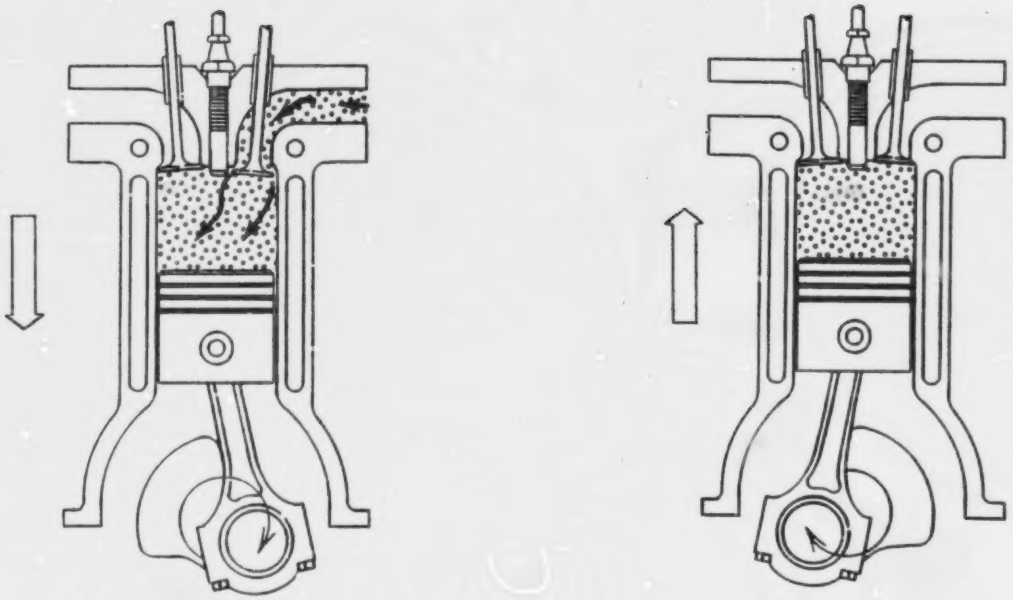

AIR
THROTTLE VALVE
AIR
GASOLINE ENGINE
ACCELERATOR
ACCELERATOR
MOTION OF RACK REGULATES FUEL DELIVERY
FUEL INJECTOR
DIESEL ENGINE

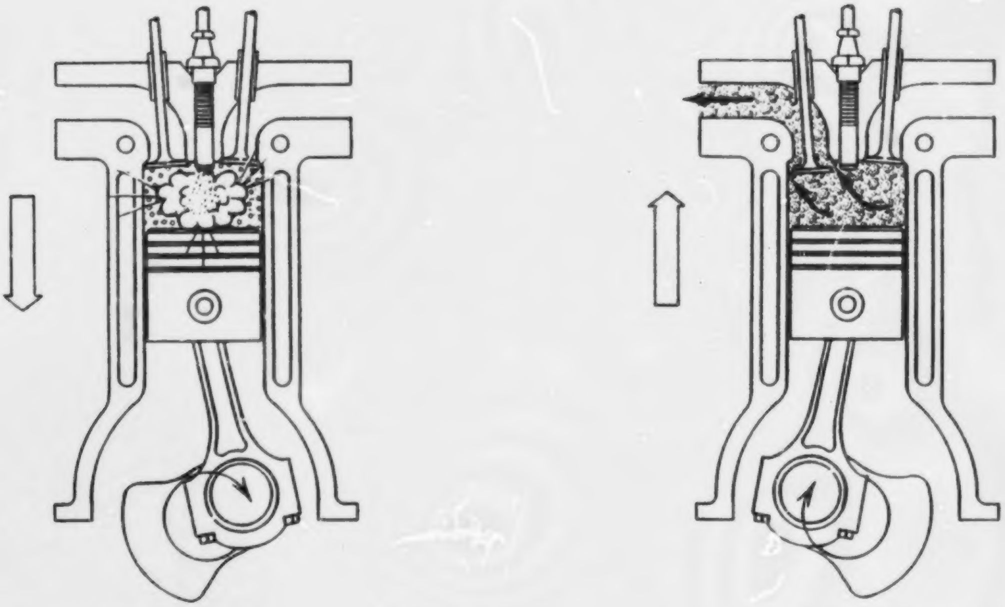
Figure 2-18. Comparison of Gasoline and Diesel Engine Regulation of Power.

TA233320



A. INTAKE STROKE

B. COMPRESSION STROKE



C. POWER STROKE

D. EXHAUST STROKE

▨ AIR

▨ AIR FUEL MIXTURE

▨ EXHAUST

Figure 2-19. Four-Stroke Cycle Diesel.

TA233321

low-speed power, and gets much more fuel mileage than the gasoline counterpart. This makes the engine very suitable for large trucks.

(2) The diesel engine requires no ignition tuneups because there is no ignition system.

(3) Because diesel fuel is of an oily consistency and less volatile than gasoline, it is not as likely to explode in a collision.

d. Disadvantages.

(1) The diesel engine must be made very heavy to have enough strength to deal with the tighter compression of the fuel and air mixture.

(2) The diesel engine is very noisy.

(3) Diesel fuel creates a large amount of fumes.

(4) Because diesel fuel is not very volatile, it is difficult to start a diesel engine in cold weather.

(5) A diesel engine operates well only in low-speed ranges in relation to gasoline engines. This creates problems when using them in passenger cars that require a wide-speed range.

e. Usage. Diesel engines are widely used in all types of heavy trucks, trains, and boats. In recent years, more attention has been focused on using diesels in passenger cars.

f. Multifuel Engine (Fig. 2-20). The multifuel engine is basically a four-stroke cycle diesel engine with the capability of operating on a wide variety of fuel oils without adjustment or modification (chapter 5, section I). The fuel injection system is equipped with a device called a fuel density compensator. Its job is to vary the amount of fuel to keep the power output constant regardless of the fuel being used. The fuel system for the multifuel engine is described in detail in chapter 5, section I. The multifuel engine uses a spherical combustion chamber to aid in thorough mixing, complete combustion, and minimizing knocks. The spherical combustion chamber is covered in chapter 5, section II.

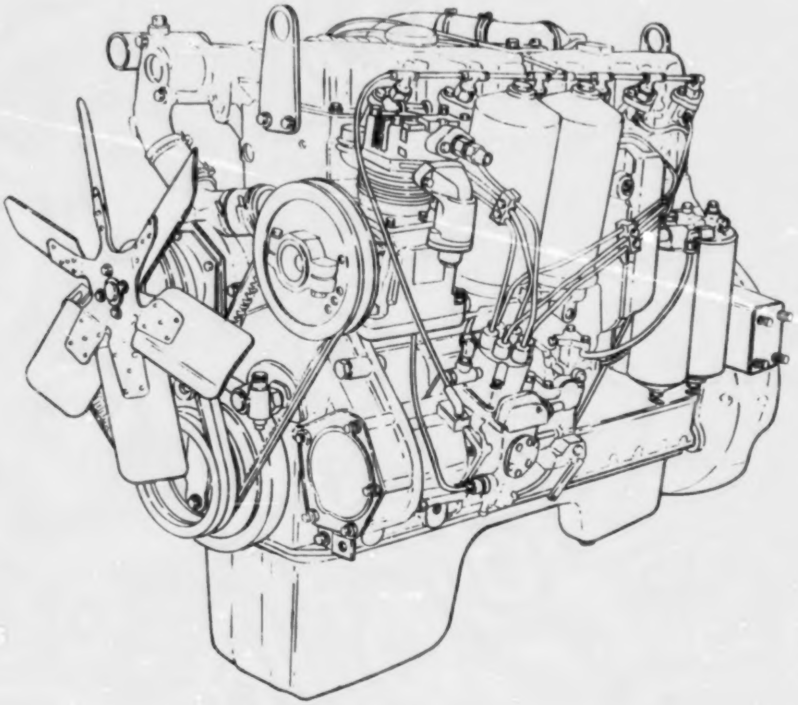


Figure 2-20. Multifuel Engine.

TA233322

2-14. Two-Stroke Cycle Diesel (Fig. 2-21).

a. *General.* The two-stroke cycle diesel is a hybrid engine sharing operating principles of both a two-stroke cycle gasoline engine and a four-stroke cycle diesel engine. The major features of the engine are as follows.

(1) It completes an operating cycle every two piston strokes or every crankshaft revolution. Like a two-stroke cycle gasoline engine, it gives a power stroke every time the piston moves downward.

(2) It is a compression ignition engine, making it a true diesel engine.

(3) It utilizes an exhaust valve on top of the combustion chamber as in a four-stroke cycle diesel engine. Intake ports are cut into the cylinder wall as in a two-stroke cycle gasoline engine.

(4) It mixes its fuel and air in the combustion chamber as in a four-stroke cycle diesel engine. The air enters through the intake ports and the fuel is injected into the combustion chamber by the fuel injection system.

(5) The air supply to the engine is constant while the speed and power output of the engine is regulated by controlling the quantity of fuel injected into the combustion chamber.

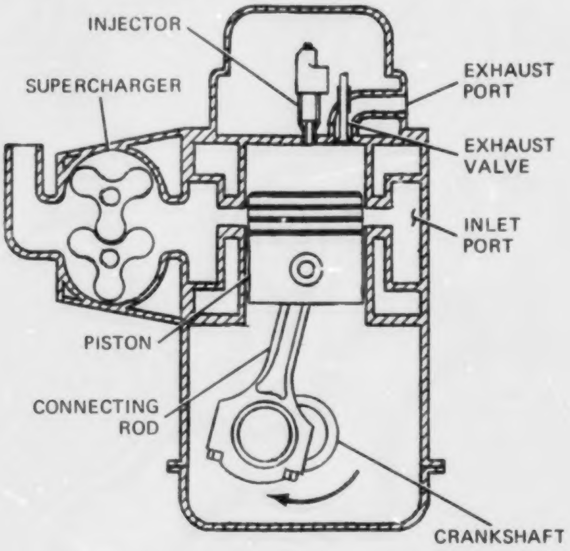


Figure 2-21. The Two-Stroke Cycle Diesel Engine.

(6) Unlike any of the other engine types, the two-stroke cycle diesel engine must have a supercharger to force the intake air into the upper cylinder. The most common type used is the rootes. Principles of supercharging are covered in chapter 4, section VI.

b. *Operation (Fig. 2-22).*

(1) *Scavenging.* Scavenging begins with the piston at bottom dead center. The intake ports are uncovered in the cylinder wall and the exhaust valve opens. Air is forced into the upper cylinder by the supercharger. As the air is forced in, the burnt gases from the previous operating cycle are forced out.

(2) *Compression.* As the piston moves toward top dead center, it covers the intake ports. The exhaust valve closes at this point. This seals the upper cylinder. As the piston continues upward, the air in the cylinder is tightly compressed. As in the four-stroke cycle diesel, a tremendous amount of heat is generated by the compression.

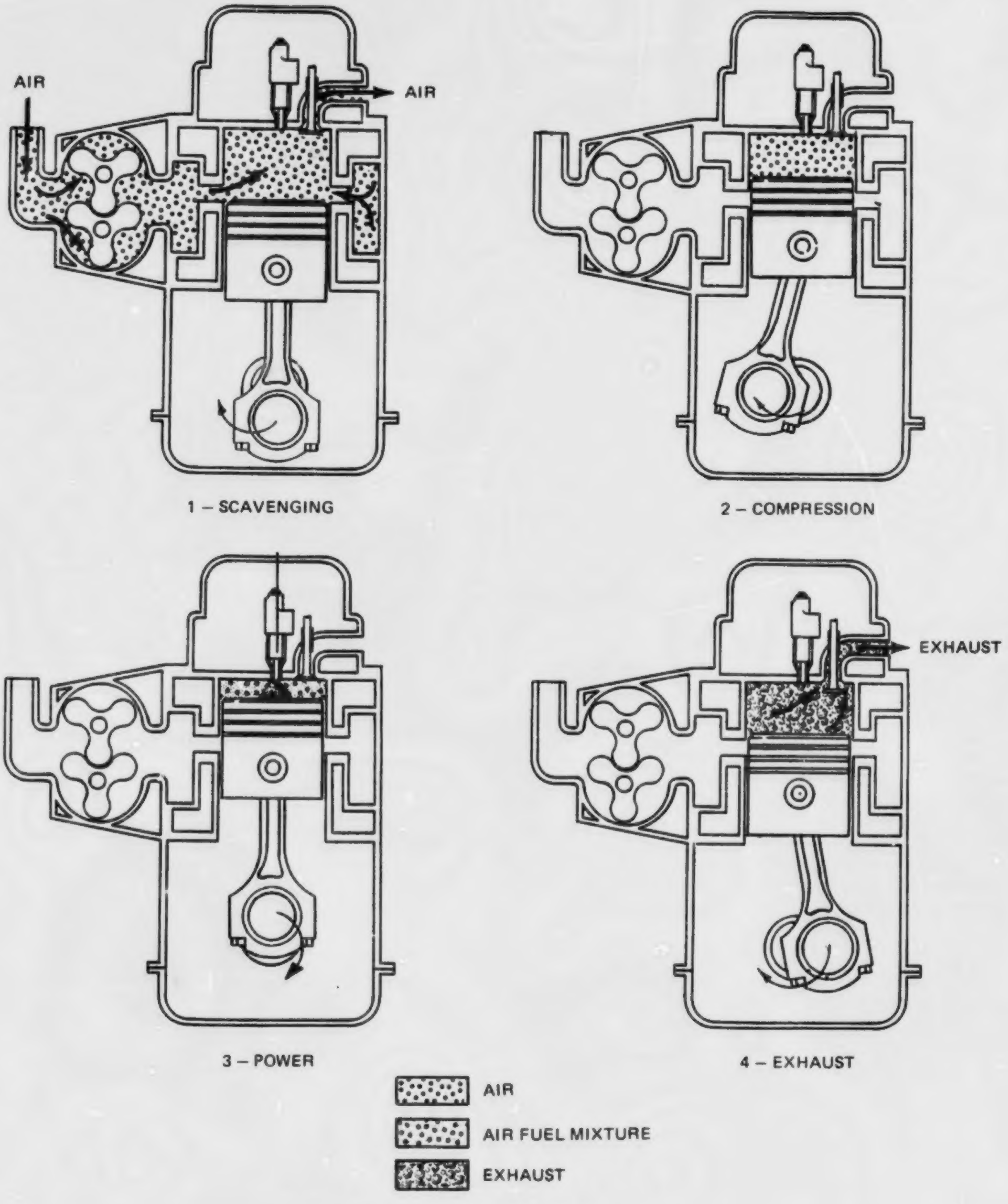
(3) *Power.* As the piston reaches top dead center, the compression stroke ends. Fuel is injected at this point. The intense heat of compression causes the fuel to ignite. The burning fuel pushes the piston down, giving power to the crankshaft. The power stroke ends when the piston gets down to the point where the intake ports are uncovered. At about this point, the exhaust valve opens and scavenging begins again.

c. *Advantages.* The two-stroke cycle diesel engine has all of the advantages that a four-stroke cycle engine has over a gasoline engine plus the following:

(1) Because it is a two-stroke cycle engine, it will run smoother than its four-stroke cycle counterpart. This is because there is a power stroke generated for every crankshaft revolution.

(2) The two-stroke cycle diesel has a less complicated valve train because it does not use intake valves.

TA233323


AIR
AIR
EXHAUST
AIR
AIR FUEL MIXTURE
EXHAUST

1 – SCAVENGING

2 – COMPRESSION

3 – POWER

4 – EXHAUST

Figure 2-22. The Two-Stroke Diesel Cycle.

d. Disadvantages.

(1) The two-stroke cycle engine must use a supercharger to force in the intake air and push out the burnt exhaust gases. This is because the movement of the piston is not such that it will accomplish this naturally. The supercharger uses engine power to run it.

TA233324

(2) The two-stroke cycle diesel uses either two or four exhaust valves per cylinder, which complicates the valve mechanism.

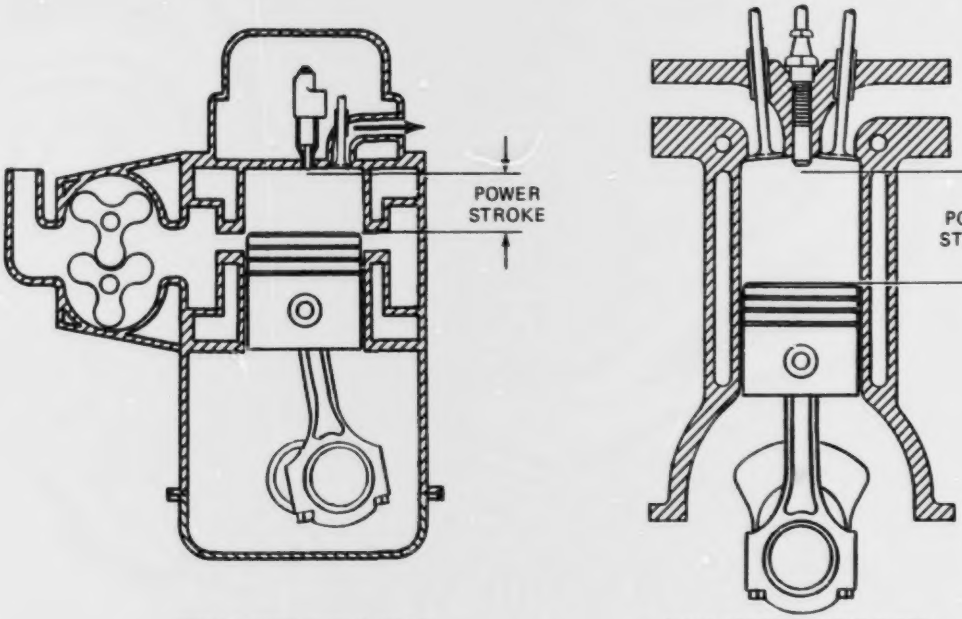
(3) As with the two-stroke cycle gasoline engine, the diesel counterpart will not produce twice as much power as a four-stroke cycle engine even though it produces twice as many power strokes. By studying figure 2-23, it can be seen that the power strokes are only a portion of the downstroke of the piston in a two-stroke cycle diesel. In a four-stroke cycle diesel, the power stroke lasts from top dead center to bottom dead center.

e. Usage. The two-stroke cycle diesel is used in most of the same applications as the four-stroke cycle diesel.

2-15. Multicylinder Engine Versus Single-Cylinder Engine.

a. General. The rotation of a crankshaft is measured by breaking up one revolution into 360 equal parts. Each part is called a degree. The standard starting point is with the piston at top dead center. Figure 2-24 illustrates how this is measured. Section I demonstrated that each piston stroke is one-half of a crankshaft revolution. This is expressed as 180 degrees of crankshaft rotation. We also can recall that there are two complete crankshaft revolutions for every four-stroke operating cycle. This is expressed as 720 degrees of crankshaft rotation.

b. Power Overlap. In a simple four-stroke cycle engine, the power stroke produces a driving force that rotates the crankshaft. This means that out of a 720-degree operating cycle, there are only 180 degrees when the crankshaft actually receives any driving force. In reality, the power stroke is actually even shorter. This is due to the fact that engineers have found that an engine will run better if the exhaust valve is set to begin opening approximately four-fifths of the way through the power stroke. This reduces the power stroke still further, to approximately 145 degrees (para 2-7). When the engine runs, it has to rely on power that is stored in the flywheel from the power stroke to push it through the 575 degrees remaining in the operating cycle. A much smoother running engine can be made by making it a multicylinder engine. A multicylinder engine



TWO-STROKE CYCLE DIESEL

FOUR-STROKE CYCLE DIESEL

Figure 2-23. Comparison of Two- and Four-Stroke Cycle Diesel Power Stroke Lengths. TA233325

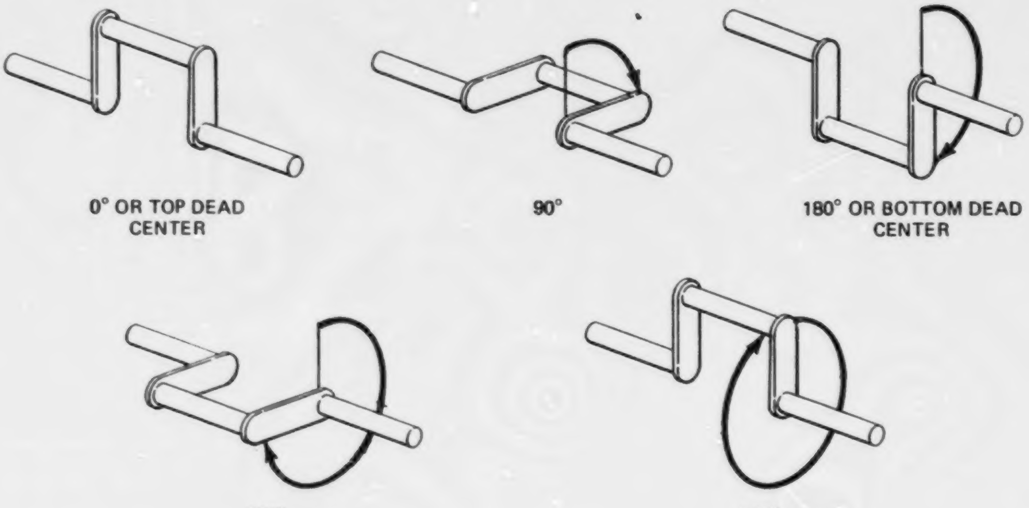


Figure 2-24. Measuring Crankshaft Rotation.

is actually more than one engine, all operating a common crankshaft. Engines in automotive use are usually built using four-, six-, or eight-cylinder engines. Whenever engines are built with more than one cylinder, it is important that the cylinders give their power strokes in equal increments of crankshaft rotation. Figure 2-25 demonstrates some typical multiple-cylinder configurations.

Figure 2-26 illustrates how much of the engine rotation is taken up by power stroke in a one-cylinder engine.

Figure 2-26 also demonstrates how the equally spaced power strokes in a four-cylinder engine reduce the periods when the flywheel is carrying the engine. With four power strokes for every 720 degrees of rotation, one can be made to begin every 180 degrees. This leaves the engine with four equally spaced periods of 35 degrees each that the flywheel must carry the crankshaft. If the engine has more than four cylinders, the power strokes overlap, meaning that before one power stroke is finished, another one begins. As illustrated in figure 2-25, a six-cylinder engine has a 25-degree power overlap between cylin-

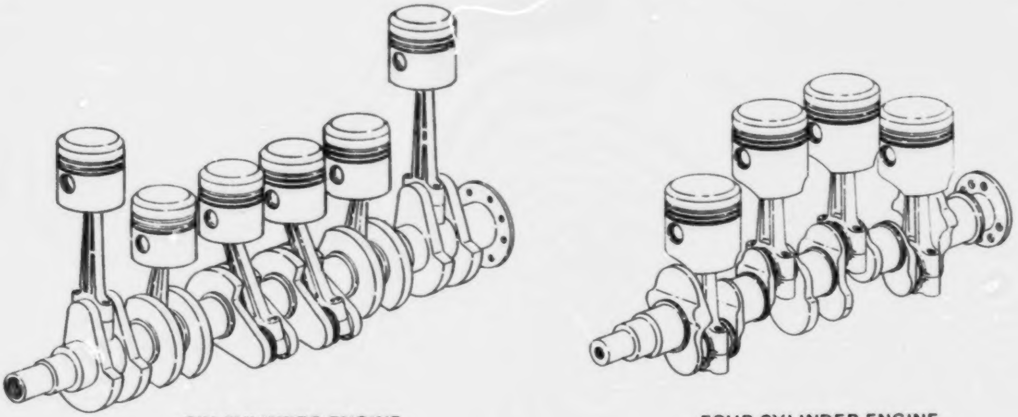
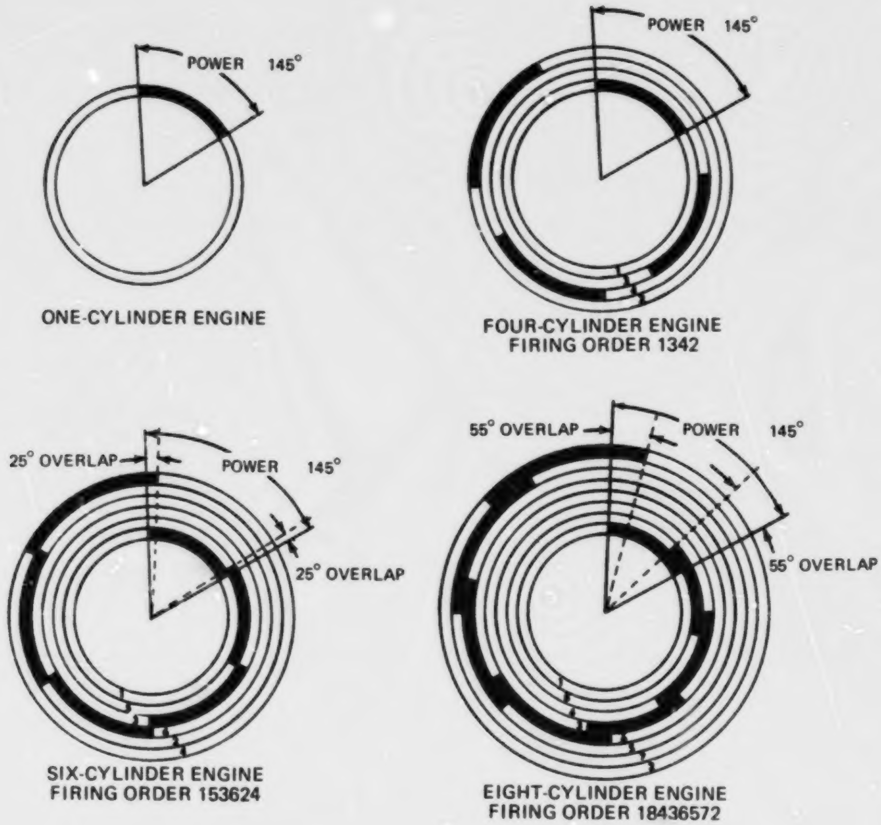


Figure 2-25. Typical Multiple-Cylinder Configurations.

TA233326



ONE-CYLINDER ENGINE

FOUR-CYLINDER ENGINE
FIRING ORDER 1342

SIX-CYLINDER ENGINE
FIRING ORDER 153624

EIGHT-CYLINDER ENGINE
FIRING ORDER 18436572

NOTE:
THE CIRCLES SHOWN ABOVE REPRESENT 720° NOT 360° BECAUSE THE CRANKSHAFT MUST ROTATE THROUGH 720° TO COMPLETE THE CYCLE ONCE FOR ALL CYLINDERS

Figure 2-26. Power Delivery in One-, Four-, Six-, and Eight-Cylinder Engines.

ders. An eight-cylinder engine has an even larger 55-degree power overlap. It becomes very obvious from figure 2-26 that the more cylinders that an engine has, the smoother the power delivery will be.

c. *Power Increase.* It also is obvious that the most practical way to increase the power output of an engine is to make a lot of small cylinders instead of one big one. A multicylinder engine is not only smoother but more reliable also. This is because each piston weighs less than a comparable size single-cylinder engine. The constant changing of direction of the piston causes more bearing wear if the piston is excessively heavy. Also, the single-cylinder engine is not as smooth, which will decrease not only the life of the engine, but also the equipment that it is operating.

2-16. Piston Engine Versus Rotary Engine.

a. *General.* A relatively new configuration of the gasoline engine, called the rotary, has reached the automotive scene within the past 25 years. Its operating cycle is exactly the same as the piston engine, consisting of intake, compression, power, and exhaust operating phases. But rather than having reciprocating pistons rotating a crankshaft, it uses a triangular-shaped rotor that rotates around inside of a specially shaped housing. The basic rotary engine is illustrated in figure 2-27. As the rotor moves around the inside of the housing, it also rotates an offcenter or eccentric shaft through an internal gear. The housing has intake and exhaust ports cast into the housing in strategically located points.

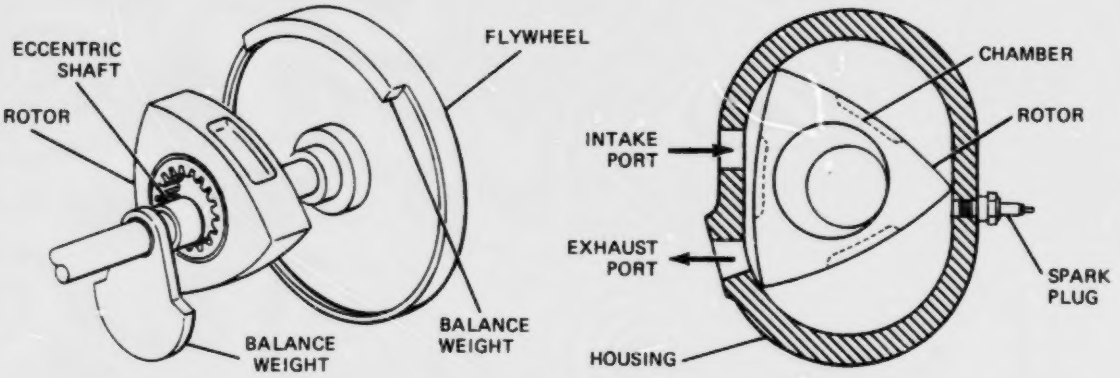


Figure 2-27. The Rotary Engine.

b. Operation (Fig. 2-28).

(1) *Intake.* Looking at the rotor face (1), note that as it moves by the intake port, the space between it and the rotor housing increases. This causes a fuel and air mixture to be drawn in through the intake port.

(2) *Compression.* As the rotor face (1) continues around the inside of the housing, it moves away from the intake port. As it moves away, the space between the rotor face and the housing decreases. This compresses the fuel and air mixture.

(3) *Power.* When the rotor face (1) reaches the point where it is compressing the fuel and air mixture the tightest, the spark plug ignites the mixture and pushes the rotor around in the housing.

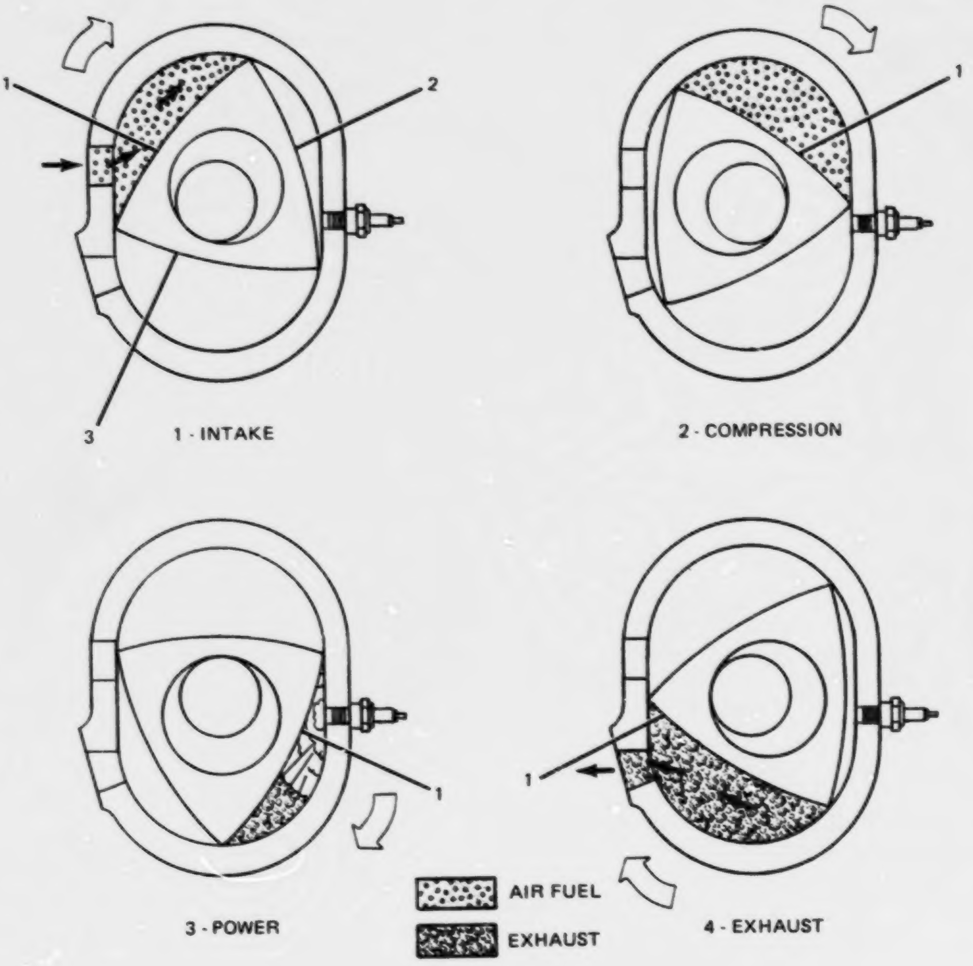
(4) *Exhaust.* As the rotor face (1) continues around, it becomes exposed to the exhaust port. At this point, the space decreases in size again. As the space size decreases, it causes the burnt gases to be pushed out through the exhaust port. This is a continuous cycle.

(5) *Three Rotor Faces.* Note the three rotor faces (1, 2, and 3) illustrated in figure 2-28. Each one of these faces goes through its own complete operating cycle every time the rotor goes around in the housing. The rotor is geared to the eccentric shaft so that it only goes around once for every three turns of the eccentric shaft. This works out to one power stroke to every eccentric shaft rotation. This is illustrated in figure 2-29.

c. Advantages. If the eccentric shaft receives one power stroke for each eccentric shaft revolution, then the rotor is equivalent to a two-piston, four-stroke cycle engine. As a result, the engine is a much more compact unit. The absence of the reciprocating parts and the absence of the valve train serve to help the engine attain higher speeds safely, giving it more flexibility in usage. The absence of these parts also serves to make this engine smoother than its piston engine counterpart.

d. Disadvantages. A large percentage of the combustion area is exposed to the intake charge because of the rotary engine design. This large surface area, when wetted with fuel during intake and ignited at the beginning of the power stroke, produces dirty combustion. While rubbing against the housing, the seals on each corner of the triangular-shaped rotor are subjected to high rotational speeds. This results in rapid seal wear and is of a major concern to manufacturers. The many irregular curves in the design make the machining processes of the rotary engine difficult. The rotary engine also is hard to modify for development purposes. The rotary engine has not had a major impact on automotive engine development. Lack of research and development have kept it from realizing its full potential.

TA233328


1
2
3
1
1
1
AIR FUEL
EXHAUST

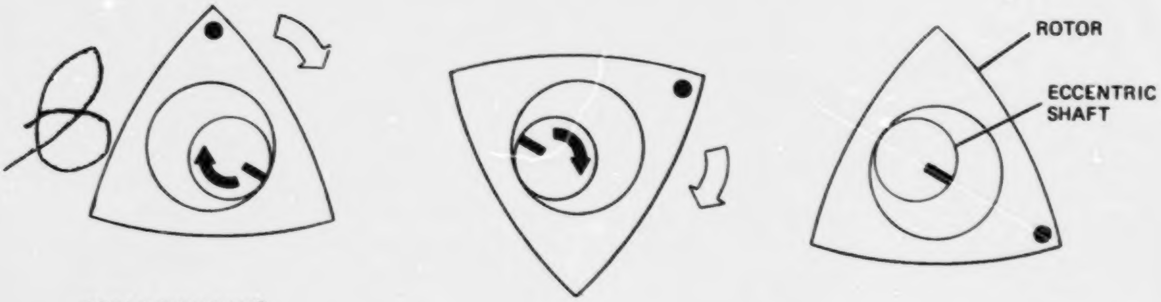
1 - INTAKE

2 - COMPRESSION

3 - POWER

4 - EXHAUST

Figure 2-28. The Rotary Engine Cycle.


ROTOR
ECCENTRIC SHAFT

ROTOR TURNS 120°
SHAFT TURNS 360°
THE RATIO BETWEEN
ROTOR AND SHAFT IS 1:3

Figure 2-29. Speed Relationship of Rotor to Eccentric Shaft.

TA233329

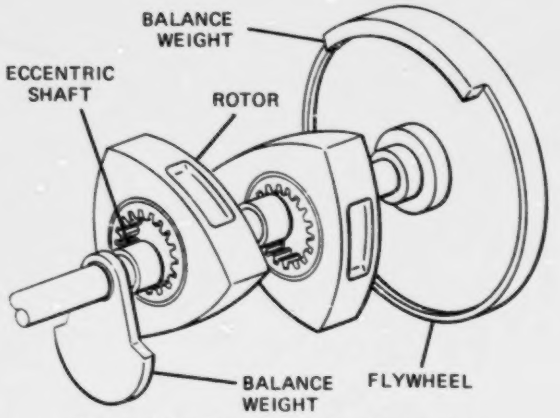


Figure 2-30. Two-Rotor Configuration.

e. Usage. Rotary engines are in use in passenger automobiles and small equipment such as snowmobiles. The engines usually are made in a two-rotor configuration as shown in figure 2-30. A two-rotor design is equivalent to a four-cylinder, four-stroke cycle piston engine.

Section III. CLASSIFICATION OF PISTON ENGINES

2-17. Classification by Methods of Cooling.

a. Air Cooled. Engines that use air as a cooling medium generally are used in aircraft and small equipment such as motorcycles, snowmobiles, and gasoline power equipment. The air-cooled engine usually is identified by removable cylinders with cooling fins covering the outside surfaces. A typical air-cooled engine is shown in figure 2-31.

b. Liquid Cooled. Engines that use liquid as a cooling medium are used in the majority of automotive applications. The liquid-cooled engine is identified by the remote radiator and associated plumbing. A typical liquid-cooled engine is shown in figure 2-32.

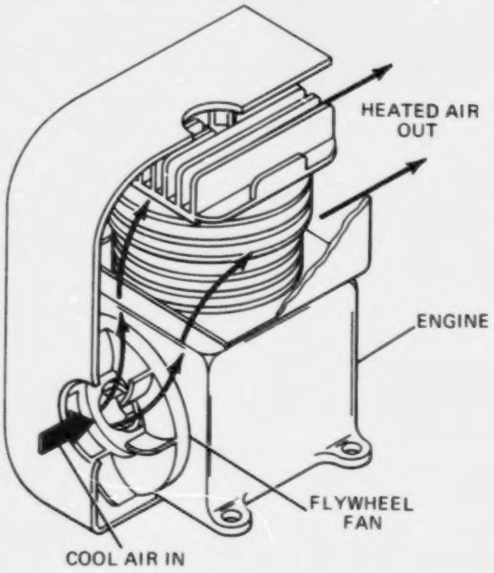


Figure 2-31. Typical Air-Cooled Arrangement.

2-18. Classification by Valve Arrangement. An engine can be classified by the arrangement of its valves and valve train configuration. The various valve train configurations may be grouped into two categories based on the location of the valves. The first category is the group of engines with the valves located beside the pistons and cylinders, in the cylinder block. The second category is the group of engines with the valves located over the pistons in the cylinder heads.

a. Valves in the Cylinder Block. These engines are known as flathead engines. This is due to the fact that the cylinder head is shaped like a flat slab. A typical flathead engine cylinder head is shown in figure 2-33. The cylinder head's only functions are to complete the combustion chamber and to hold and locate the spark plug. Flathead engines are virtually obsolete in all current automotive applications. The configuration of valve trains that were used in flathead engines are as follows.

(1) *T-Head (Fig. 2-34).* The intake and the exhaust valves were located on opposite sides of the cylinder, each requiring their own camshaft. The T-head engine got its name from the imaginary letter formed by the piston and the valve heads.

TA233330

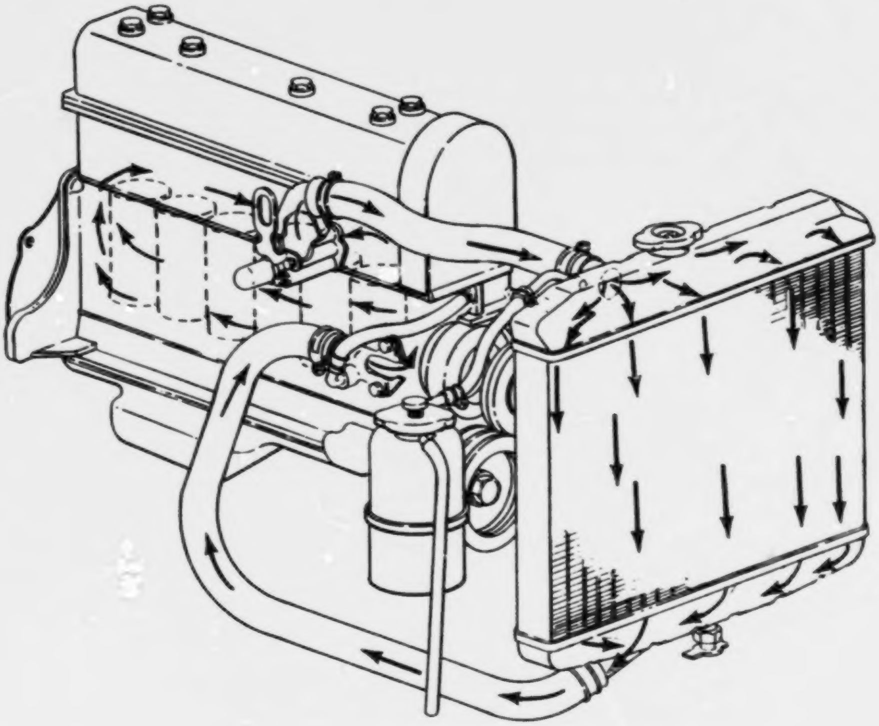
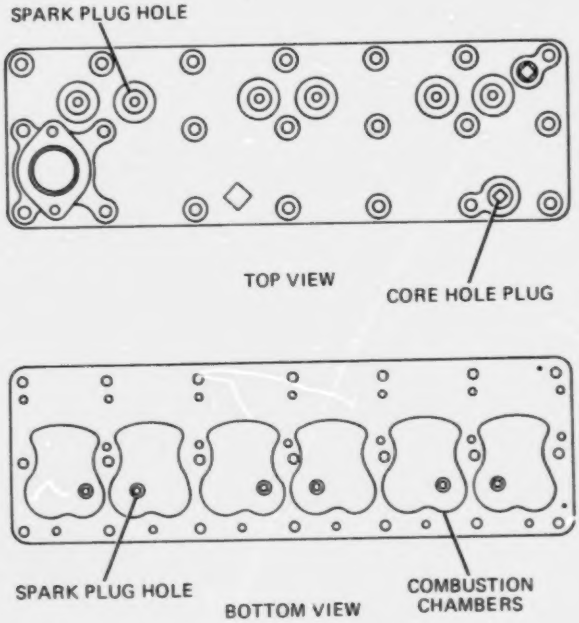
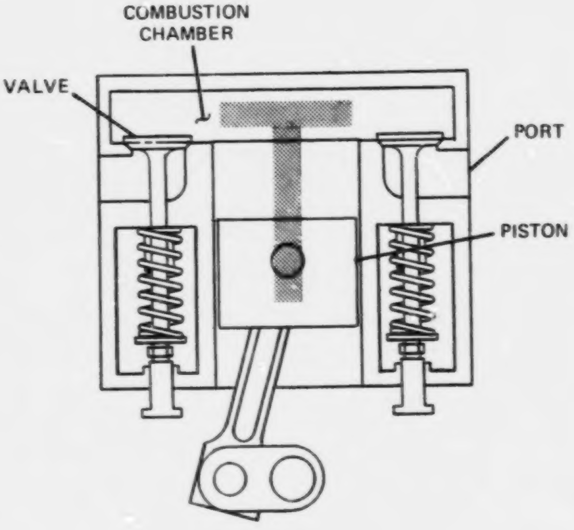


Figure 2-32. Typical Liquid-Cooled Arrangement.



SPARK PLUG HOLE
TOP VIEW
CORE HOLE PLUG
SPARK PLUG HOLE
BOTTOM VIEW
COMBUSTION CHAMBERS

Figure 2-33. Typical Flathead Cylinder Head.



COMBUSTION CHAMBER
VALVE
PORT
PISTON

Figure 2-34. T-Head Engine.

TA233331

(2) *L-Head (Fig. 2-35).* The intake and the exhaust valves were both located on the same side of the piston and cylinder. The L-head engine was a much simpler design than the T-head because it required only one camshaft. The L-head engine got its name from the imaginary letter formed by the piston and the valve heads.

b. Valves in the Cylinder Head. These engines come in two groups. The first group have their camshafts located in their cylinder blocks. These engines are known as the overhead valve (ohv) engines. The second group have their camshafts located in their cylinder heads. These engines are known as the overhead camshaft (ohc) engines. A typical ohv cylinder head is shown in figure 2-36. The configurations of valve trains for engines with the valves in the head are as follows.

(1) *I-Head (Fig. 2-37).* This configuration has its camshaft located in the cylinder block. The camshaft operates the valves through the lifter, push rod, and rocker arm. The I-head gets its name from the letter formed by the piston and the valve. Although this configuration is the most popular for current gasoline and diesel engines, it is rapidly being superseded by overhead camshaft configurations in passenger cars.

(2) *Single Overhead Camshaft (Fig. 2-38).* This configuration has its camshaft located in the cylinder head. When the single overhead camshaft configuration is used, the intake and the exhaust valves are both operated from a common camshaft. The valve train may be arranged to operate the valves directly through the lifters as shown in view A. The valve train also may be arranged to operate the valves through rocker arms as shown in view B. The single overhead camshaft configuration is rapidly becoming the most popular one for passenger car gasoline engines.

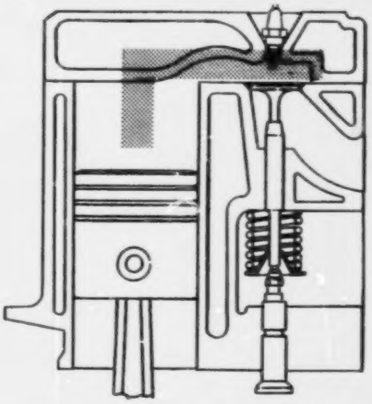


Figure 2-35. L-Head Engine.

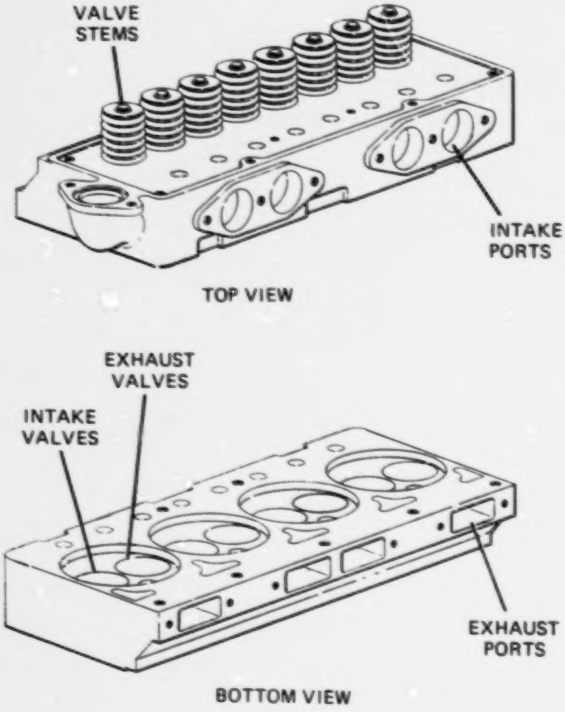


Figure 2-36. Typical Overhead Valve Cylinder Head.

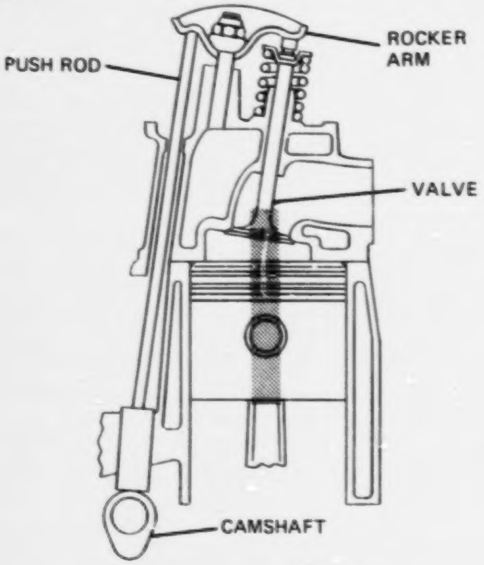


Figure 2-37. I-Head Engine. TA233332

BEST COPY AVAILABLE

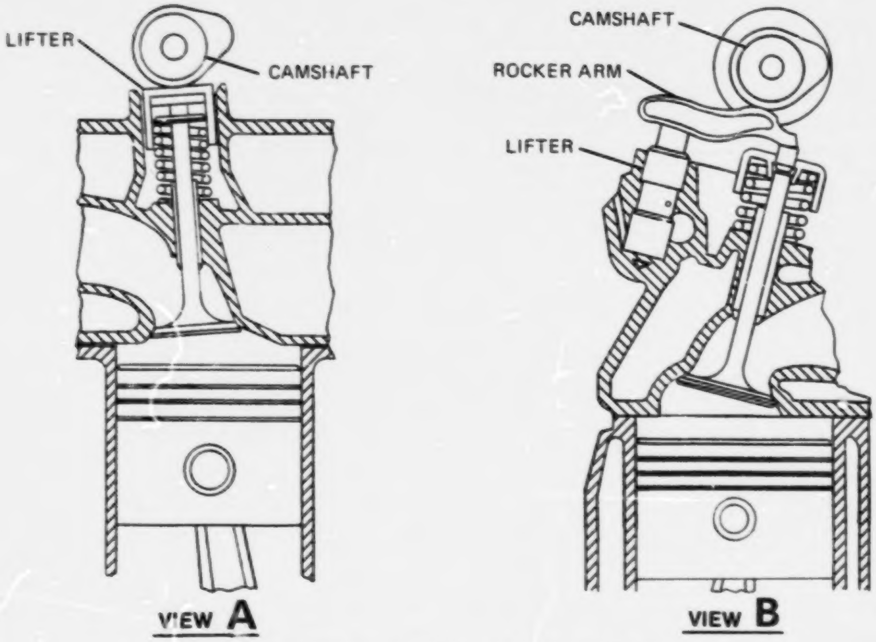


Figure 2-38. Single Overhead Camshaft Configurations.

(3) *Double Overhead Camshaft (Fig. 2-39).* This configuration has its camshafts located in the cylinder head. When the double overhead camshaft is used, the intake and the exhaust valves each operate from a separate camshaft. Each camshaft operates the valves directly through the lifters. This configuration, though cumbersome, provides the most engine performance and is used mostly in more expensive automotive applications.

c. F-Head Engines (Fig. 2-40). The F-head engine is a combination of the two valve arrangement groups. In this engine, the intake valves are of the overhead type, located in the cylinder head. The exhaust valves, however, are located in the cylinder block. The engine gets its name by the imaginary letter F formed by the cylinder and the valve heads. This configuration usually is not used in current automotive design.

2-19. Classification by Cylinder Arrangement. Multicylinder engines are classified by cylinder arrangement. Each cylinder arrangement has its own advantages. The most common arrangements are shown in figure 2-41.

a. In line (A, Fig. 2-41). This is a very common arrangement in automotive and truck applications alike. It is commonly built in four- and six-cylinder configurations. Until approximately 30 years ago, it was common to build an in-line engine with eight cylinders. As the cars became shorter and wider, the in-line eight-cylinder engine was replaced by the V-arrangement.

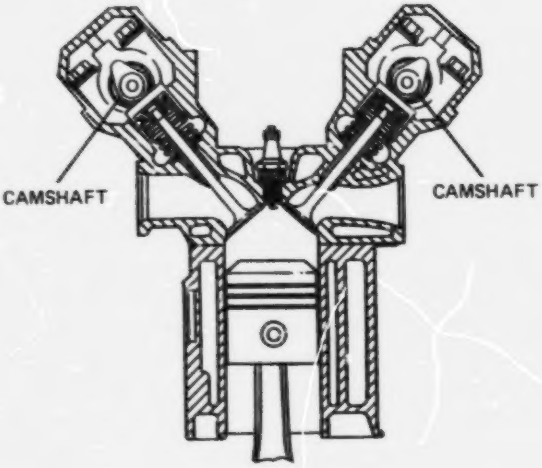


Figure 2-39. Double Overhead Camshaft Configuration. TA233333

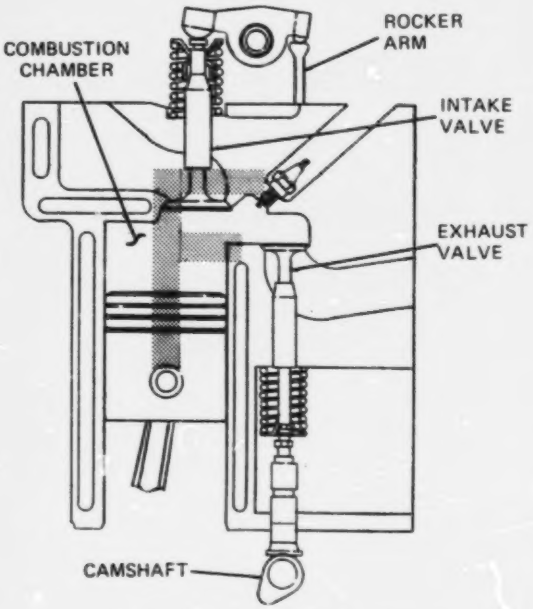
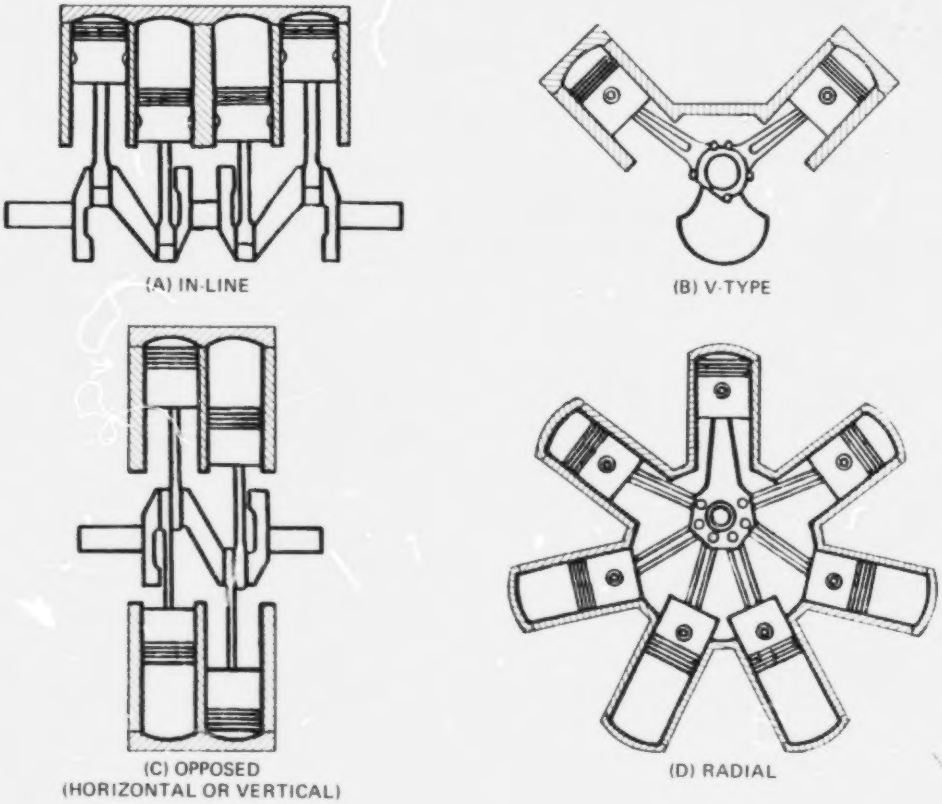


Figure 2-40. F-Head Engine.

b. V-Type (B, Fig. 2-41). This is also a very common arrangement in automotive and truck applications. The cylinders usually are arranged at 90 degrees to each other with opposing cylinders sharing a common crankpin. The V-type engine, in the eight-cylinder configuration, has replaced the in-line eight-cylinder engine in automotive applications for two reasons.

(1) The V-type engine is much shorter, making it more suitable for modern body styles.

(2) The V-type engine has a much shorter crankshaft that is less subject to torsional vibration (para 3-9). This makes the V-type engine smoother than the in-line engine. For exactly the same reasons as above, the V-type engine is replacing the in-line engine in six-cylinder configurations. A V-type engine in a six-cylinder configuration is suitable for front-wheel drive compact cars where the engine is mounted transversely (sideways).


(A) IN-LINE

(B) V-TYPE

(C) OPPOSED
(HORIZONTAL OR VERTICAL)

(D) RADIAL

Figure 2-41. Typical Cylinder Arrangements.

TA233334

c. Horizontal Opposed (C, Fig. 2-41). Less common than the in-line and the V-type, this engine is designed to fit in compartments where height is a consideration. The cylinders are arranged at 180 degrees to each other with opposing cylinders sharing a common crankshaft journal. This engine arrangement almost always is used for air-cooled configurations, although at least one auto manufacturer is using a horizontally opposed, water-cooled engine in their product.

d. Radial (D, Fig. 2-41). The radial engine has cylinders placed in a circle around the crankshaft. The crankshaft has only one throw, with one of the pistons connected to this throw by a master rod. The connecting rods from the other pistons are fastened to the crankshaft through this master rod. This engine is almost exclusively an aircraft engine and is of little interest when studying automotive technology.

Section IV. ENGINE MEASUREMENTS

2-20. Bore and Stroke (Fig. 2-42).

a. Bore. The bore is the diameter of the cylinder.

b. Stroke. The stroke is the distance that the piston travels as it moves from top dead center to bottom dead center.

2-21. Piston Displacement (Fig. 2-42). Piston displacement is the volume of space that the piston displaces as it moves from top dead center to bottom dead center. The piston displacement is used to express engine size. To find the displacement of an eight-cylinder engine with a bore of 4 in. (10.16 cm) and a stroke of 3 in. (7.62 cm), do the following.

a. Find the area of the cylinder bore. To find the area of the cylinder bore, use the formula:

Area of cylinder bore = $0.785 \times \text{diameter}^2 = 0.785D^2$

Area of cylinder bore = $0.785 \times 4^2 = 0.785 \times 16 = 12.56$

Area of cylinder bore = 12.56 sq in. (81.02 sq cm).

b. Multiply the area of the cylinder bore by the stroke.

12.56 sq in. x 3 in. = 37.68 cu in. (617.37 cc)

This is the piston displacement for one cylinder.

c. Multiply the displacement of one cylinder by the number of cylinders that the engine has.

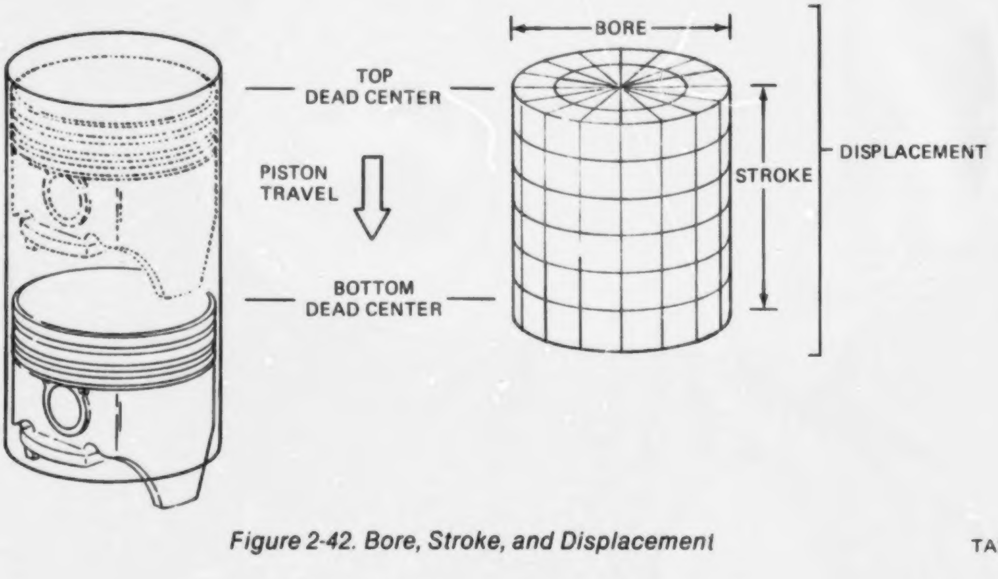


Figure 2-42. Bore, Stroke, and Displacement

TA233335

BEST COPY AVAILABLE

37.68 cu in. x 8 cylinders =
301.44 cu in. (4938.96 cc)

The displacement of the engine would be expressed as 301 cu in. in the English system. To express the displacement of the engine in the metric system, convert the cubic centimeter figure to liters. This is done by dividing the cubic centimeters by 1000. This is because 1 liter = 1000 cc.

$$\frac{4938.96}{1000} = 4.93896 \text{ liters}$$

The displacement of the engine would be expressed as 4.9 liters in the metric system.

2-22. Vacuum in Cylinder on Intake Stroke.

a. *The Atmosphere.* The earth is surrounded by an ocean of air that is known as the atmosphere. Because it is colorless and odorless, people are not always aware of it. However, the atmosphere does have weight. Figure 2-43 illustrates a theoretical setup for measuring the weight of air. Note the platform balance with a box on each side. One box appears to be an empty container, but it is really full of air. The other box is sealed and all of the air has been removed. This box will contain nothing; this is known as a vacuum. Both boxes are exactly 1 cu ft in size. With both boxes on the platform balance, the box containing the air is heavier than the box that is a vacuum. After placing 1 1/4 oz (35.4 g) of weight on the side of the balance that holds the box with the vacuum, note that both sides of the platform balance will be equal in weight. This demonstration, of course, would be very difficult to really do, but it clearly illustrates that air weighs approximately 1 1/4 oz (35.4 g) per cubic ft.

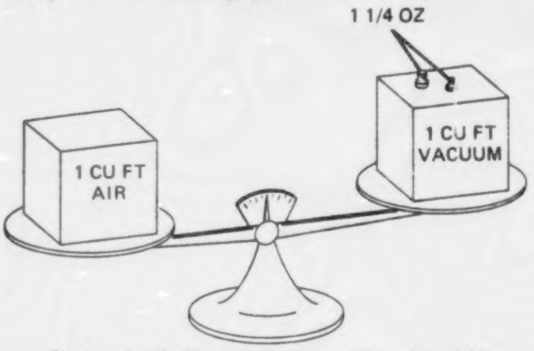


Figure 2-43. Illustrating the Weight of Air.

b. *Atmospheric Pressure (Fig. 2-44).* Elevation is always referred to in relation to the level of the oceans. This is known as sea level. Because the atmosphere extends for many miles above the earth, the weight of all of this air creates a large force on the earth's surface. In fact, the weight of the air creates a pressure of approximately 14.7 psi (101.3 kPa) on all things at sea level. As the elevation increases, this atmospheric pressure progressively decreases.

c. *Vacuum in the Cylinder (Fig. 2-45).* When the piston moves downward on the intake stroke, it may appear that it is sucking the mixture into the cylinder. Actually, what is really happening is that by the piston moving downward, it is making a larger space in the cylinder that contains nothing (a vacuum). The atmospheric pressure outside the cylinder will then push its way in through the intake port, filling the cylinder.

2-23. Volumetric Efficiency.

a. *General.* Volumetric efficiency is a way of measuring an engine's ability to take in, or aspirate, its intake mixture. As the piston moves down on the intake stroke, atmospheric pressure will push the intake mixture into the cylinder. Under ideal conditions, the volume of mixture that enters the engine for each intake stroke would be exactly equal to the displacement of the cylinder. This is rarely the case in a real-life situation for the following reasons:

(1) The intake stroke happens so quickly that the mixture cannot get into the cylinder fast enough to fill it to its full capacity. For this reason an engine generally will have a higher volumetric efficiency at lower speeds than it will at higher speeds.

(2) As the mixture passes through the engine on its way to the cylinder, it picks up heat. As the mixture heats up, it becomes less dense. This means that less mixture actually enters the cylinder.

(3) Sharp bends, obstructions, and rough surfaces on the walls of the intake ports will slow down the intake mixture, decreasing volumetric efficiency.

b. *Measuring Volumetric Efficiency.* Volumetric efficiency is expressed as a ratio of the

TA233336

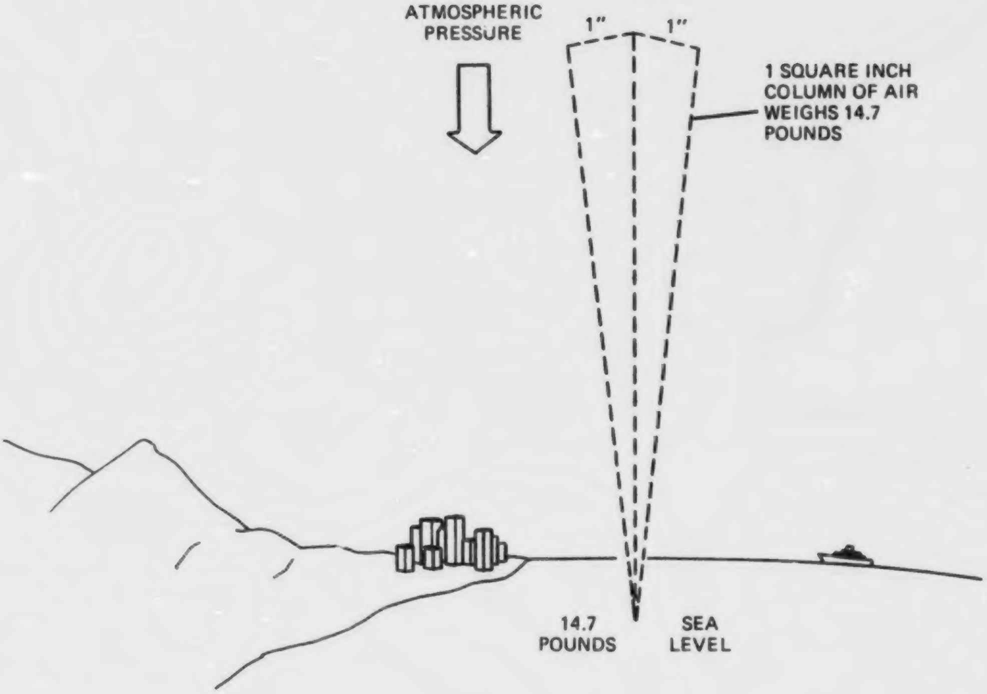

ATMOSPHERIC PRESSURE
1"
1"
1 SQUARE INCH COLUMN OF AIR WEIGHS 14.7 POUNDS
14.7 POUNDS
SEA LEVEL

Figure 2-44. Atmospheric Pressure at Sea Level.

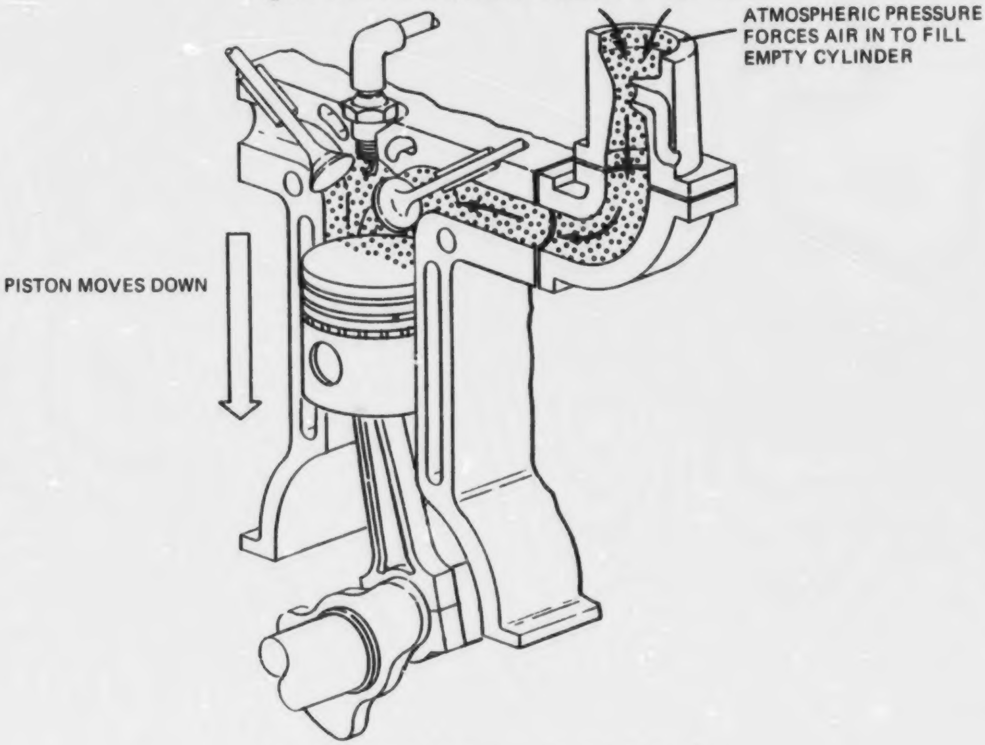

ATMOSPHERIC PRESSURE FORCES AIR IN TO FILL EMPTY CYLINDER
PISTON MOVES DOWN

Figure 2-45. Vacuum in the Cylinder.

TA233337

amount of mixture that enters the cylinders on the intake stroke to the amount of mixture that the cylinders could actually hold. Figure 2-46 demonstrates a typical engine with a volumetric efficiency of 80 percent. As the piston moves from top to bottom dead center, the cylinder volume increases by 100 cu in., yet only 80 cu in. of air enters the cylinder.

c. Increasing Volumetric Efficiency. Any increase in volumetric efficiency will increase engine performance. Volumetric efficiency may be increased by doing the following.

(1) Keep the intake mixture cool (fig. 2-47). By ducting intake air from outside of the engine compartment and keeping the fuel cool, the intake mixture can be kept cooler. The cooler the mixture is, the higher the volumetric efficiency will be. This is because a cool mixture is denser or more tightly packed.

(2) Modify the intake passages (fig. 2-48). Any changes to the intake passages that make it easier for the mixture to flow through will cause an increase in volumetric efficiency. Other changes include reshaping ports to smooth out bends, reshaping the back of the valve heads, or polishing the inside of the ports.

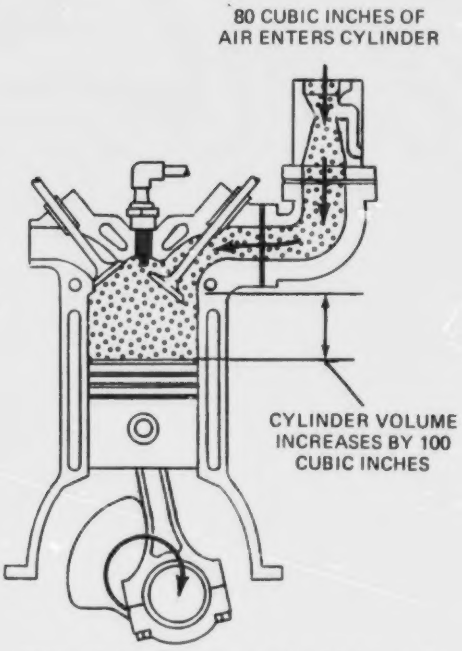


Figure 2-46. Demonstrating Volumetric Efficiency.

(3) By altering the time that the valves open or how far they open, volumetric efficiency can be improved.

(4) By supercharging and turbocharging, the volumetric efficiency figure can be brought to over 100 percent. Principles of supercharging and turbocharging are covered in detail in chapter 4.

2-24. Compression Ratio (Fig. 2-49).

a. General. The compression ratio is the method that is used universally to measure how tightly the mixture is squeezed during the compression stroke.

b. Measuring Compression Ratio. The compression ratio is found by measuring the volume that the mixture occupies when the piston is at bottom dead center, and dividing it by the volume that the mixture occupies when the piston is at top dead center. The following example illustrates this concept: For a given engine, the volume of the space occupied by the mixture is 80 cu in. when the piston is at bottom dead center. As the piston moves to top dead center, the mixture is squeezed into an area with a volume of 10 cu in. To calculate the compression ratio, do the following:

(1) Divide the volume at bottom dead center by the volume at top dead center.

$$\frac{80 \text{ cu in.}}{10 \text{ cu in.}} = 8$$

(2) Put the quotient into the form of a ratio.

Compression ratio = 8:1

This simply means that the mixture is compressed to one-eighth of its original volume.

TA233338

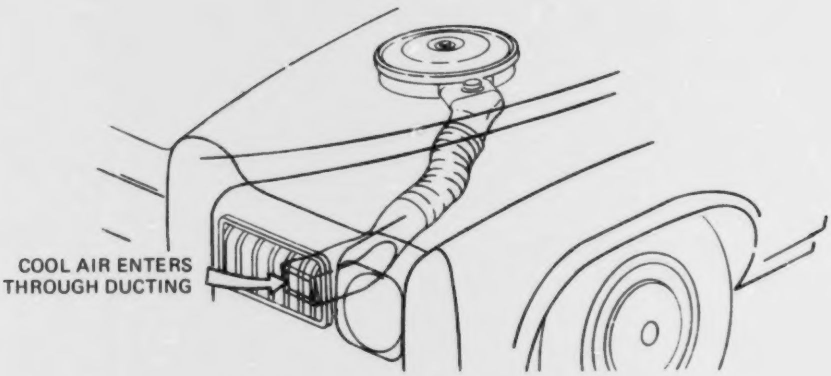

COOL AIR ENTERS
THROUGH DUCTING

Figure 2-47. Fresh Air Intake System.

c. Effect of Compression Ratio. As the compression ratio is increased, the mixture is squeezed into a tighter space. This means that there is a higher initial pressure at the start of the power stroke and that the burning gases have further to expand. For these reasons, any increase in compression ratio will effect an increase in engine power output. Passenger car engines that are modified for competition usually receive a boost in compression ratio by installing pistons with domes, or by shaving material off of the surface of the cylinder head as shown in figure 2-50. Both of these actions will serve to reduce the volume of the combustion chamber, raising the compression ratio. The limiting factor when increasing compression ratio is finding a fuel that will not ignite itself from the heat of compression, causing detonation. Detonation is covered in detail in paragraph 4-40.

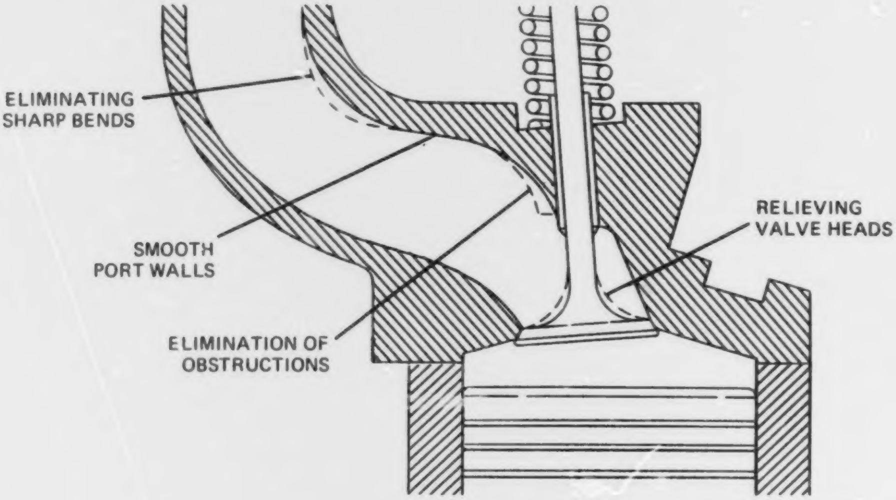

ELIMINATING
SHARP BENDS
SMOOTH
PORT WALLS
ELIMINATION OF
OBSTRUCTIONS
RELIEVING
VALVE HEADS

Figure 2-48. Port Design Consideration.

TA233339

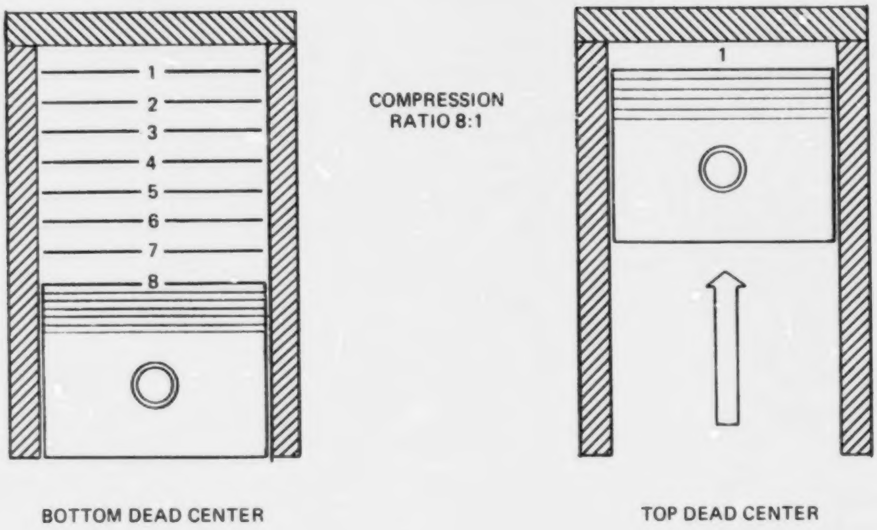

1
2
3
4
5
6
7
8
COMPRESSION RATIO 8:1
1
BOTTOM DEAD CENTER
TOP DEAD CENTER

Figure 2-49. Compression Ratio.

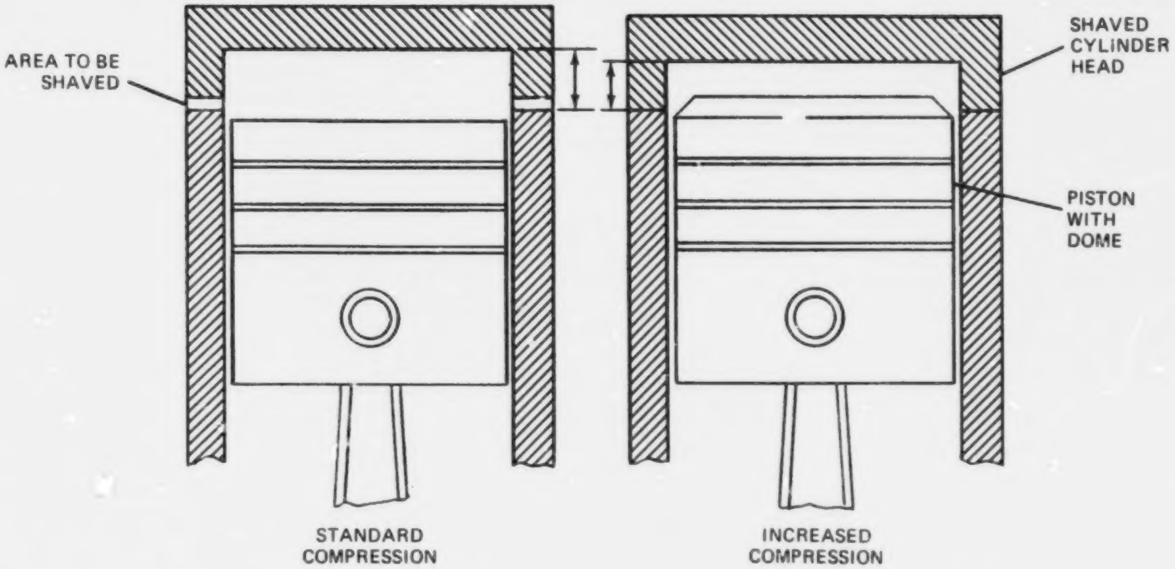

AREA TO BE SHAVED
SHAVED CYLINDER HEAD
PISTON WITH DOME
STANDARD COMPRESSION
INCREASED COMPRESSION

Figure 2-50. Increasing Compression Ratio.

Section V. TIMING

2-25. Ignition Timing.

a. General. Ignition timing refers to the timing of the spark at the spark plug gap in relation to the position of the piston.

b. Measuring Ignition Timing (Fig. 2-51). The standard way to express the time when the ignition spark occurs is by citing the respective crankshaft position in degrees. This position is expressed in terms that use top dead center for the

TA233340

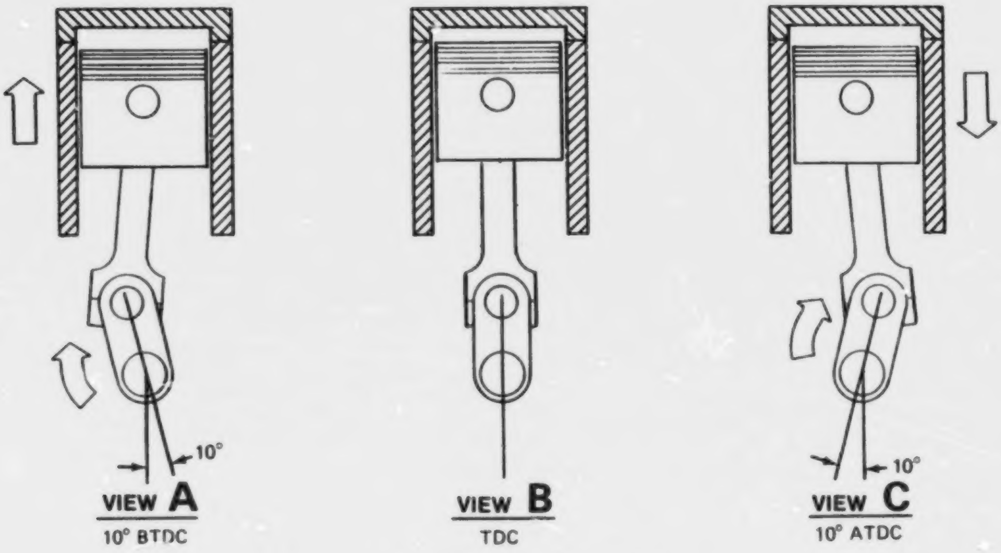

10°
VIEW A
10° BTDC
VIEW B
TDC
10°
VIEW C
10° ATDC

Figure 2-51. Ignition Timing.

piston as a baseline. This is the top dead center position that ends the compression stroke and begins the power stroke (the top dead center position that ends the exhaust stroke and begins the intake stroke has nothing to do with ignition timing). Any piston position that is before top dead center is referred to as btdc. Any piston position that is after top dead center is referred to as atdc. The positions are then further defined by giving the exact degree position of the crankshaft. In view A, the spark occurs at 10 degrees before top dead center. In view B, the spark occurs at top dead center. In view C, the spark occurs at 10 degrees after top dead center.

c. Effect of Increasing Ignition Timing (Fig. 2-52). After looking at the basic operation of a gasoline engine, it seems reasonable to assume that the engine will run fine if the spark occurs when the piston is at top dead center. In reality

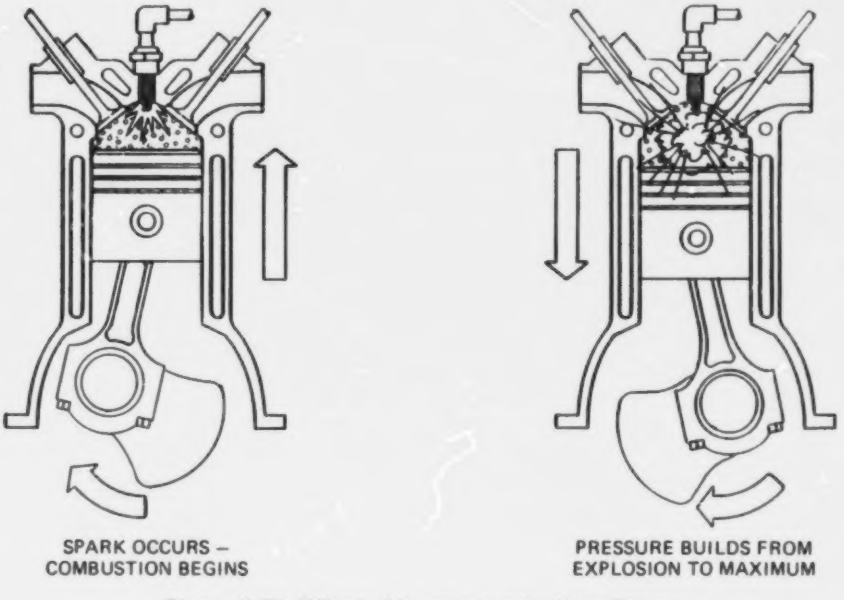

SPARK OCCURS –
COMBUSTION BEGINS
PRESSURE BUILDS FROM
EXPLOSION TO MAXIMUM

Figure 2-52. Effect of Increasing Ignition Timing.

TA233341

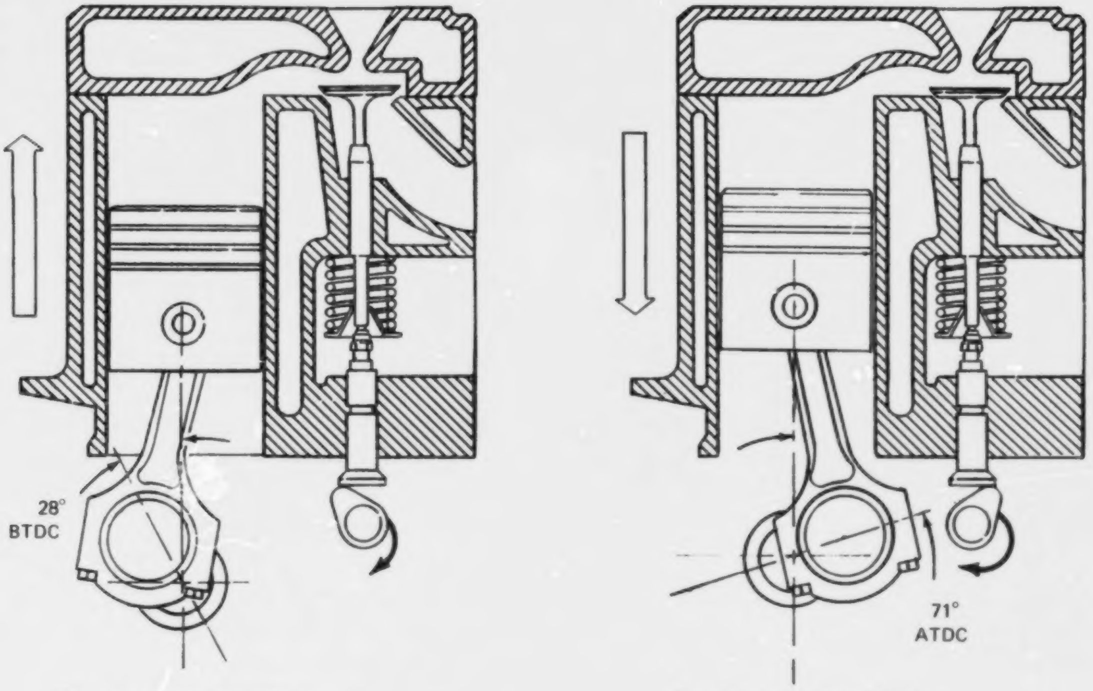
however, this is not the case. Even though the compressed mixture burns very quickly, it does take a certain amount of time for the pressure to rise in the combustion chamber. Because of this time lag, it is desirable to have the spark occur before the piston reaches top dead center. This way there is time for the pressure in the combustion chamber to rise to its maximum as the piston reaches top dead center. This, in turn, allows the piston to get the maximum push from the combustion. If the spark occurs too late into the power stroke, very little of the push from the combustion is utilized. This is because the piston already will be moving away by the time the gases start expanding from the combustion. This will reduce greatly the amount of pressure that is exerted on the piston and much power would be lost. The limiting factor to timing advance is that it can cause detonation. Detonation is covered in detail in paragraph 4-40.

d. Ignition Timing and Engine Speed. It is desirable to have ignition progressively advance as engine speed increases. This is because there is less time for the pressure to build in the combustion chamber as the speed increases. By making the spark happen earlier (as much as 30 degrees btdc) at high speeds, there is more time for the pressure to build in the combustion chamber. There are timing advance mechanisms built into most ignition systems. They will be discussed in detail in paragraph 15-8.

2-26. Valve Timing.

a. General. Valve timing is a system developed for measuring in relation to the crankshaft position (in degrees), the points when the valves open, how long they stay open, and when they close. Valve timing is probably the single most important factor in tailoring an engine for specific needs. By altering valve timing, an engine can be made to produce its maximum power in a variety of speed ranges. The following factors together make up a valve operating sequence.

b. Opening and Closing Point. The opening and closing points are the positions of the crankshaft (in degrees) when the valve just begins opening and just finishes closing. Typical opening and closing points are illustrated in figure 2-53. Note the intake valve opening 28 degrees before top dead center and closing at 71 degrees after bottom dead center.



VALVE BEGINS TO OPEN

VALVE FINISHES CLOSING

Figure 2-53. Opening and Closing Points of the Valve.

TA233342

c. Duration. Duration is the amount of crankshaft rotation (in degrees) that a given valve will remain open. In figure 2-54, a typical intake valve cycle is illustrated. The duration that it remains open is a total of 279 degrees.

d. Valve Overlap. Valve overlap is a period in the four-stroke cycle when the intake valve opens before the exhaust valve closes. Typical valve overlap is illustrated in figure 2-55. The intake valve is opening 28 degrees before top dead center for the beginning of the intake stroke. The exhaust valve is remaining open for 45 degrees after top dead center and into the intake stroke. This gives a valve overlap of 73 degrees.

e. Valve Timing Considerations. Throughout the crankshaft revolution, the speed of the piston changes. From a stop at the bottom of the stroke, the piston will reach its maximum speed halfway through the stroke and gradually slow to a stop as it reaches the end of the stroke.

The piston will behave exactly the same on the downstroke. There are two periods of crankshaft rotation in which there is almost no perceptible movement of the piston. One of these periods begins at approximately 15 to 20 degrees before top dead center and ends at approximately 15 to 20 degrees after top dead center. The other period begins at approximately 15 to 20 degrees before bottom dead center and ends at approximately 15 to 20 degrees after bottom dead center. These two positions are illustrated in figure 2-56. These two periods of crankshaft rotation are utilized when establishing a valve timing sequence as follows.

(1) During the period that occurs at top dead center, valve overlap is introduced to increase volumetric efficiency. By opening the intake valve before the exhaust valve is closed, the intake mixture is pulled in by the momentum of the exiting exhaust gas. The intake mixture coming in also helps to sweep or scavenge the cylinder of exhaust gases. Because the overlap occurs during one of the periods of little piston movement, there is no problem with exhaust being pushed into the intake port or exhaust gas being pulled into the cylinder through the exhaust port by the piston.

(2) During the period that occurs at bottom dead center, the pressure remaining in the cylinder at the end of the power stroke is utilized by opening the exhaust valve early. When the exhaust valve opens, the pressure in the cylinder starts pushing the exhaust gas out of the cylinder.

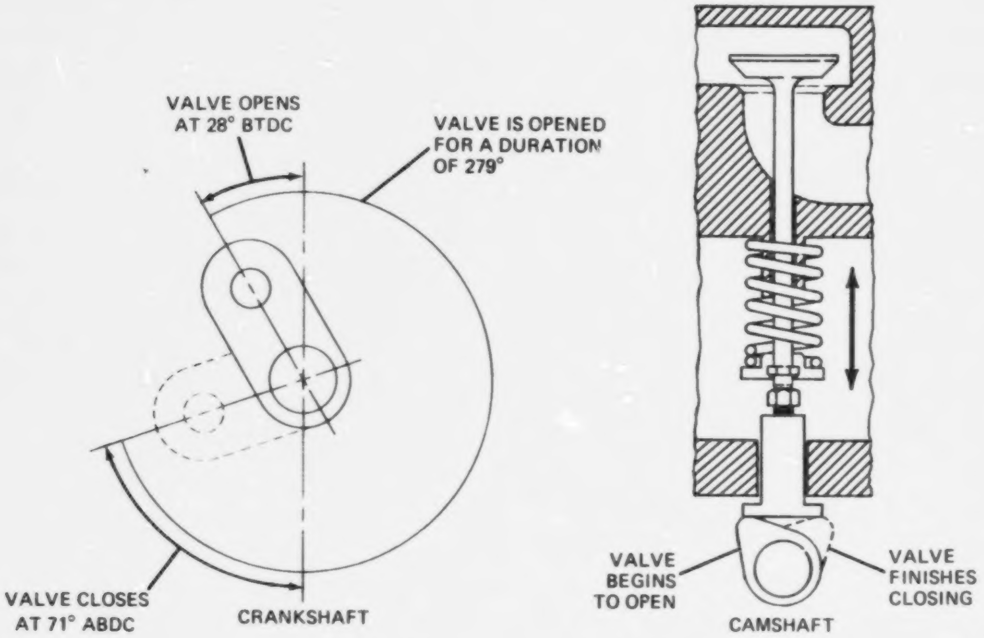


Figure 2-54. Valve Opening Duration.

TA233343

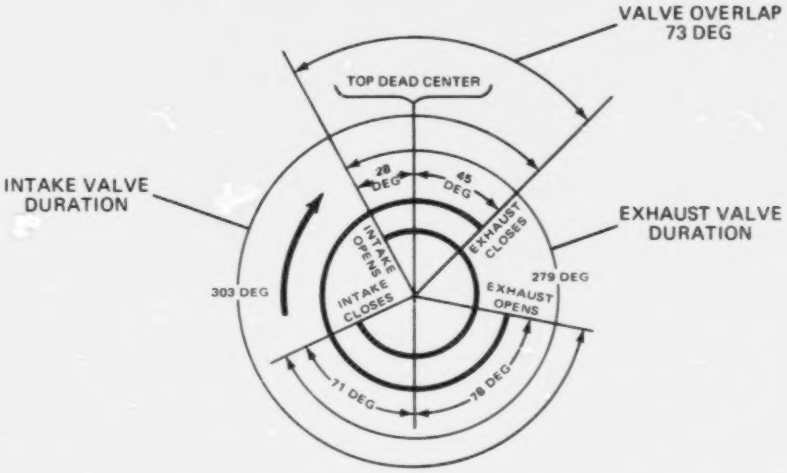

VALVE OVERLAP
73 DEG
TOP DEAD CENTER
INTAKE VALVE DURATION
EXHAUST VALVE DURATION
28 DEG
45 DEG
INTAKE OPENS
EXHAUST CLOSES
303 DEG
279 DEG
INTAKE CLOSES
EXHAUST OPENS
71 DEG
78 DEG

Figure 2-55. Valve Timing Diagram Showing Valve Overlap

Because the final 15 to 20 degrees of the power stroke have almost no piston movement, there is no problem with exhaust being drawn in by the piston.

As stated earlier, engines can be designed to produce power in a specific speed range by altering valve timing. By increasing the valve duration and overlap, an engine can be made to produce more power in the higher speed ranges. This is because the exiting exhaust gas will have more inertia, making its scavenging effect last longer. This same engine will run poorly at low speed due to the piston having a tendency to pull exhaust back into the cylinder and blow it back up into the intake port.

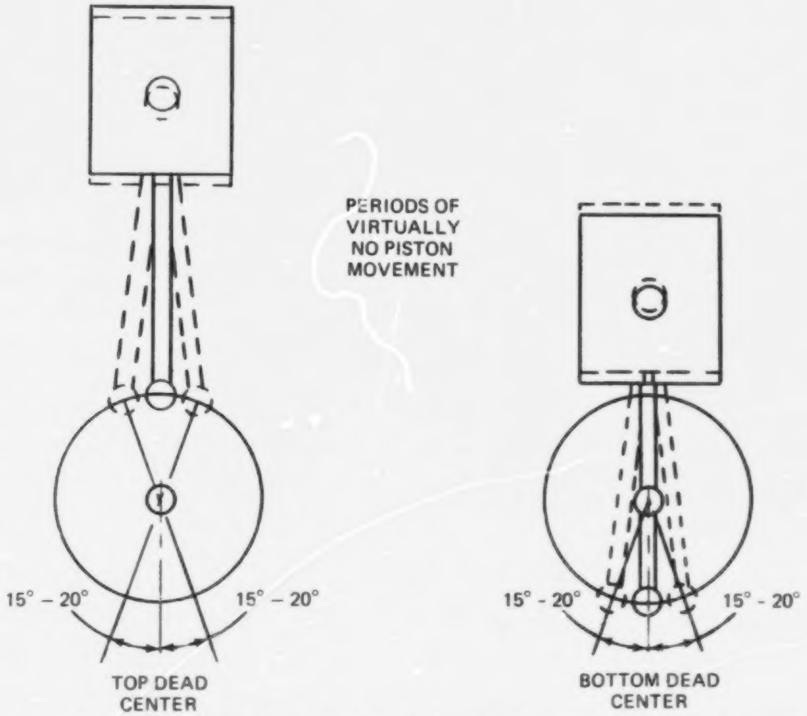

PERIODS OF
VIRTUALLY
NO PISTON
MOVEMENT
15° – 20°
15° – 20°
TOP DEAD
CENTER
15° - 20°
15° - 20°
BOTTOM DEAD
CENTER

Figure 2-56. Crankshaft Rotational Periods of Imperceptible Piston Movement.

TA233344

Section VI. ENGINE OUTPUT

2-27. Work (Fig. 2-57). Work is the movement of a body against an opposing force. Work is measured in units of foot pounds (Newton meters). One foot pound of work is the equivalent of lifting a 1-lb weight 1 ft. When sliding something horizontally, work is measured by the force required to move the object multiplied by the distance that it is moved. Note that work is always the force exerted over a distance. Also note that if there is no movement of the object, then there is no work accomplished, no matter how much force is applied.

2-28. Energy (Fig. 2-58).

a. General. Energy is the ability to do work. Energy takes many forms, such as heat, light, sound, stored energy (potential), or an object in motion (kinetic energy).

b. Energy at Work. Energy performs work by changing from one form into another. To illustrate this, consider the operation of an automobile. From start to finish, it will do the following.

(1) When it is sitting still and not running, it has potential energy stored in the gasoline.

(2) To set it into motion, the gasoline is burned, changing its potential energy into heat energy. The auto's engine then transforms the heat energy from the burning gasoline into kinetic energy by forcing the car into motion.

(3) The action of stopping the auto is accomplished by the brakes. By the action of friction, the brakes will transform the kinetic energy of the auto back into heat energy. Friction is covered in detail in paragraph 34-1. When all of this kinetic energy is transformed into heat energy, the auto will be stopped. The heat energy will then dissipate into the air. It is very easy to see that work was accomplished when the automobile was set into motion. It may not be as easy to see that work was also accomplished to stop the automobile. Because stopping requires applying a force over a distance, it also fits the definition of work.

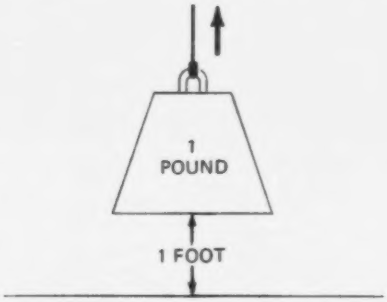


Figure 2-57. One Foot Pound of Work.

2-29. Power (Fig. 2-59). Power is the rate of work. Engines are rated by the amount of work that they can do in 1 minute. The unit of measure for rating engines is called horsepower. The horsepower unit was developed about the time that steam engines were being developed. Through testing, it was found that the average horse could lift a 200-lb weight to a height of 165 ft in 1 minute. The equivalent of one horsepower can be reached by multiplying 165 ft by 200 lb (work formula) for a total of 33,000 ft lb per minute.

2-30. Torque Effect (Fig. 2-60). Torque is a force that, when applied, tends to result in the twisting of the object rather than its physical movement. When measuring torque, the force that is applied must be multiplied by the distance from the axis of the object. Because the force in pounds (Newtons) is multiplied by distance in feet (meters), torque is expressed in terms of pound feet (Newton meters). When applying torque to an object, the force and the distance from the axis will be dependent on each other. For example, if a 100-ft lb torque is applied to a nut, a 100-lb force would be applied if the wrench were 1-ft long. If a 2-ft-long wrench were used, a 50-lb force is all that would be necessary.

2-31. Prony Brake. (Fig. 2-61). The prony brake is a device that measures the actual usable horsepower of an engine. It is used very little today, but is understood very easily. This makes it very useful for learning the concept of horsepower-measuring devices.

The device consists of a flywheel that is surrounded by a large braking device. An arm is attached to this braking device with its other end exerting pressure on a scale. In operation, the engine is attached to, and drives, the flywheel. The

TA233345

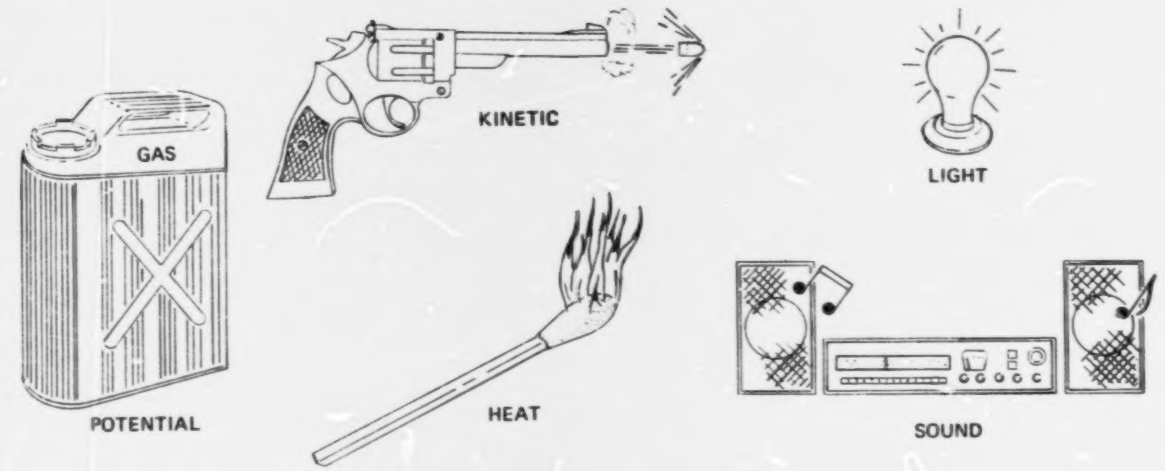


Figure 2-58. Forms of Energy.

braking device is tightened until the engine is slowed to a predetermined rpm. As the braking device slows the engine, the arm attached to it exerts pressure on a scale. Based on the reading at the scale and the engine rpm, a brake horsepower value is calculated by using the following formula:

$$\frac{6.28 \times \text{length of arm} \times \text{engine rpm} \times \text{scale reading}}{33{,}000}$$

It must be noted that the figures 6.28 and 33,000 are constants in the formula, meaning that they never change. For example, a given engine exerts a force of 300 lb on the scale through a 2-ft-long arm when the brake device holds the engine's speed at 3,000 rpm. By using the formula, calculate the brake horsepower as follows:

$$\frac{6.28 \times 2 \times 3000 \times 300}{33{,}000} = \text{342.55 brake horsepower}$$

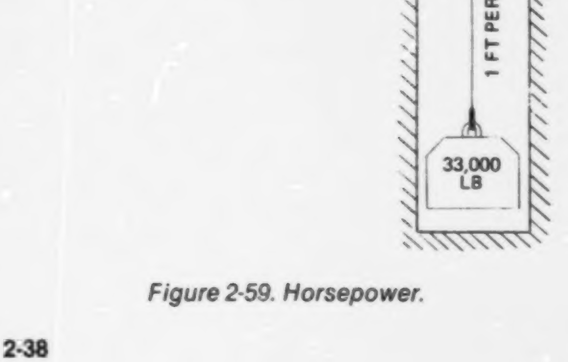


Figure 2-59. Horsepower.

2-32. Dynamometer (Fig. 2-62).

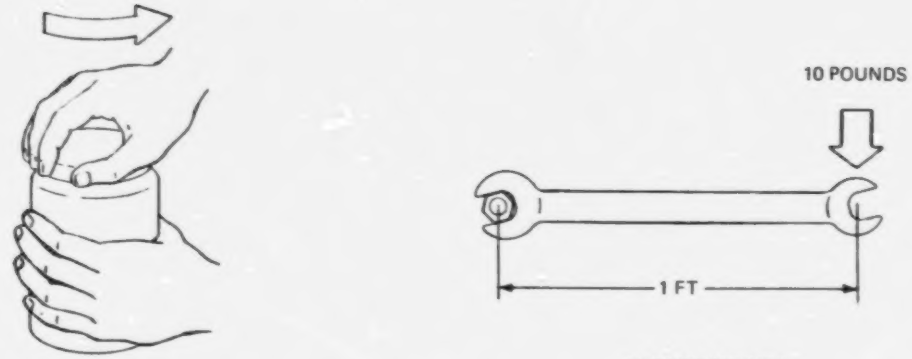
a. General. The modern method for checking engine power output is by using a dynamometer. The dynamometer can be used to check the output of the engine at the crankshaft or the horsepower of the engine can be measured at the driving wheels of the automobile by using a chassis dynamometer.

b. Types of Dynamometers. The dynamometer, like the prony brake, loads an engine down to a given rpm and measures the torque that it produces at that given speed. There are two basic types of dynamometers.

(1) One type of dynamometer uses a large electrical generator to which the engine is attached. The engine brake horsepower then can be calculated by converting the electrical power generated into horsepower readings.

(2) Another type of dynamometer uses a water brake to absorb engine power and calculate brake horsepower.

TA233346


10 POUNDS
1 FT

10 FOOT-POUNDS
OF TORQUE

REMOVING A JAR LID

Figure 2-60. Torque Effect.

c. Converting Torque to Work (Fig. 2-63). The amount of work that is accomplished when a torque is given can be calculated if the amount of movement in complete revolutions also is given. (Remember, there is no work accomplished unless there is movement.)

For example: a 100-ft lb torque is applied to a shaft to rotate it six times. How much work is accomplished? Work can be found with the following formula:

6.28 x number of rotations x torque,

therefore:

6.28 x 6 x 100 ft lb = 3,768 ft lb.

d. Engine Torque (Fig. 2-64). The engine exerts torque to drive the automobile. The amount of torque produced by the engine generally will increase with speed within the engine's operational range. As the speed increases beyond the operational range, the engine torque will fall off. This is because of decreases in volumetric efficiency at excessive speed.

2-33. Torque-Horsepower-Speed (RPM) Relationship. Figure 2-65 shows the relationship between speed, torque, and horsepower for a given engine. As illustrated in figure 2-65, horsepower will continue to increase with speed even after torque begins to fall off. The reason that this happens is because horsepower is dependent on speed and torque. The horsepower will

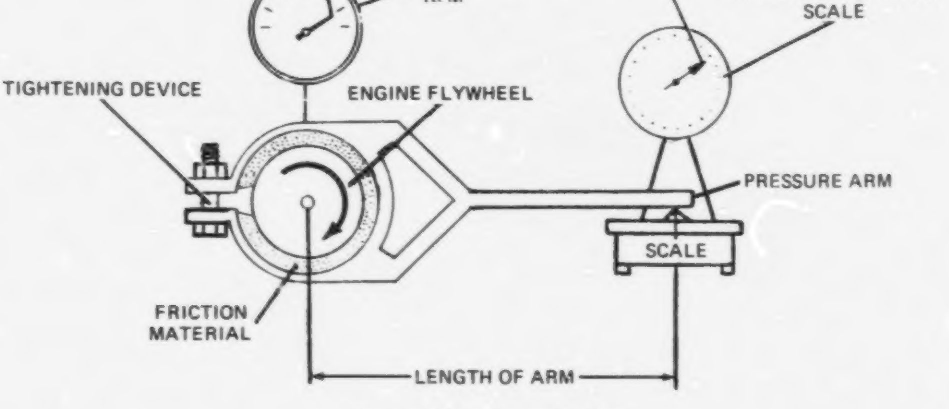
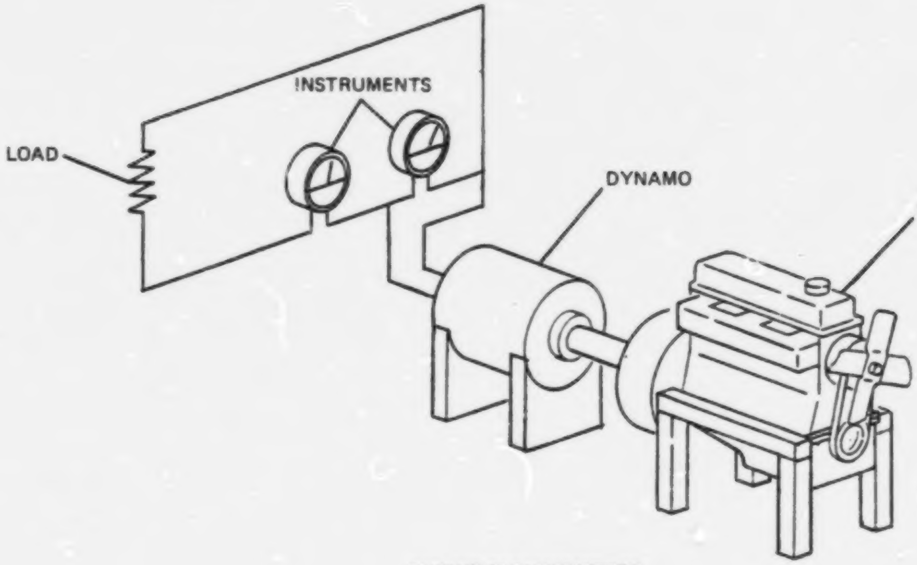
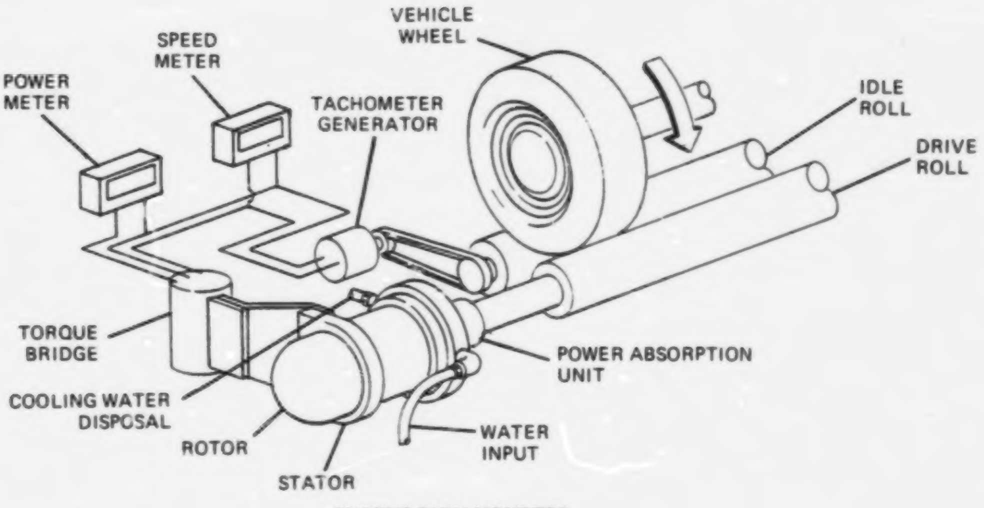

3000 RPM
ENGINE RPM
300 LB
WEIGHT READING ON SCALE
TIGHTENING DEVICE
ENGINE FLYWHEEL
PRESSURE ARM
SCALE
FRICTION MATERIAL
LENGTH OF ARM

Figure 2-61. Prony Brake.

TA233347


INSTRUMENTS
LOAD
DYNAMO
ENGINE

ENGINE DYNAMOMETER


VEHICLE WHEEL
SPEED METER
POWER METER
TACHOMETER GENERATOR
IDLE ROLL
DRIVE ROLL
TORQUE BRIDGE
POWER ABSORPTION UNIT
COOLING WATER DISPOSAL
WATER INPUT
ROTOR
STATOR

CHASSIS DYNAMOMETER

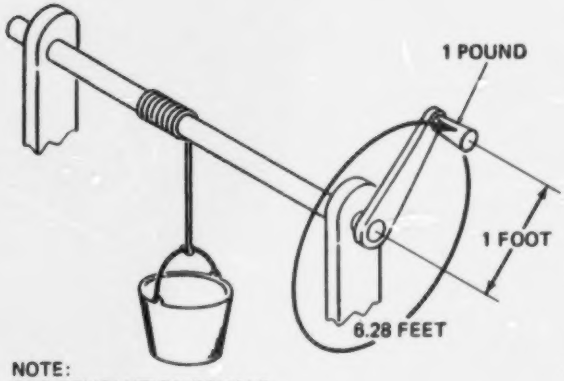
Figure 2-62. Dynamometers.

continue to increase due to the speed increase offsetting the torque decrease. At a point, however, the torque begins to fall off so sharply that the increase in speed cannot offset it and horsepower also falls off. The brake-horsepower formula from paragraph 2-31 can clearly show that horsepower, speed, and torque are all dependent on each other by doing the following.

a. Given the brake-horsepower formula:

$$\frac{6.28 \times \text{length of arm} \times \text{engine rpm} \times \text{scale reading}}{33{,}000}$$

TA233348



NOTE:
ONE REVOLUTION EQUALS
6.28 FOOT-POUNDS OF WORK.

Figure 2-63. Conversion of Torque to Work.

b. Torque can be substituted into the formula because it is equal to the length of the arm times the scale reading. This yields:

$$\frac{6.28 \times \text{torque} \times \text{engine rpm}}{33{,}000}$$

c. This can be simplified further by dividing the 33,000 constant by the 6.28 constant. This provides a formula that shows a direct torque-horsepower-speed relationship:

$$\text{Brake horsepower} = \frac{\text{torque} \times \text{rpm}}{5{,}254}$$

2-34. Rated Speed. The rated speed as indicated in figure 2-65 is the speed at which the governor in a military vehicle is set. The rated speed usually is just under the maximum horsepower speed. Operation over the rated speed, causes disproportionate engine wear and excessive fuel consumption.

2-35. Gross and Net Horsepower. The gross horsepower of an engine is the amount of power the engine delivers without any accessories or a muffler. Net horsepower is the horsepower left to propel the automobile after the requirements of all of the accessories have been deducted from the gross horsepower.

2-36. Indicated Horsepower. Indicated horsepower is the power developed inside of the engine based on the pressure developed in the cylinders. It is always much higher than the brake horsepower because it does not consider friction or the inertia of the reciprocating masses within the engine.

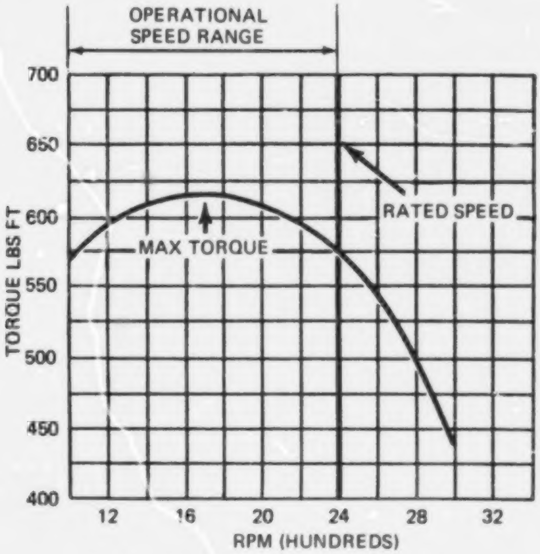


Figure 2-64. Torque Output Versus Speed.

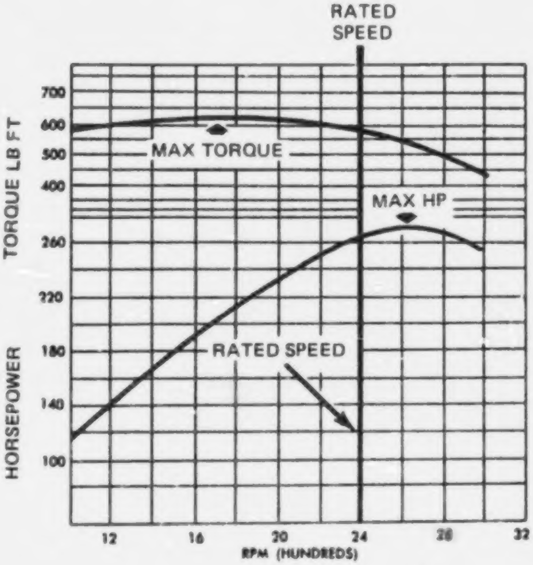


Figure 2-65. Torque-Horsepower-Speed Relationship.

TA233349

Section VII. ENGINE EFFICIENCY

2-37. Frictional Losses (Fig. 2-66). Efficiency is the relationship between results obtained and the effort required to obtain those results. Efficiency is expressed as follows:

$$\text{Efficiency} = \frac{\text{output}}{\text{input}}$$

System efficiency can be calculated using this formula. For example, if a 90-lb box was lifted with a rope and pulley, it would require a force of 100 lb. Therefore:

$$\text{Efficiency} = \frac{\text{output}}{\text{input}} \times 100 \quad =$$

$$\frac{90\,\text{lb}}{100\,\text{lb}} = 90\,\text{percent.}$$

The above results simply mean that only 90 percent of the total effort used for lifting the box actually went to that task. The remainder, or 10 percent of the effort, was lost to frictional forces within the pulley system.

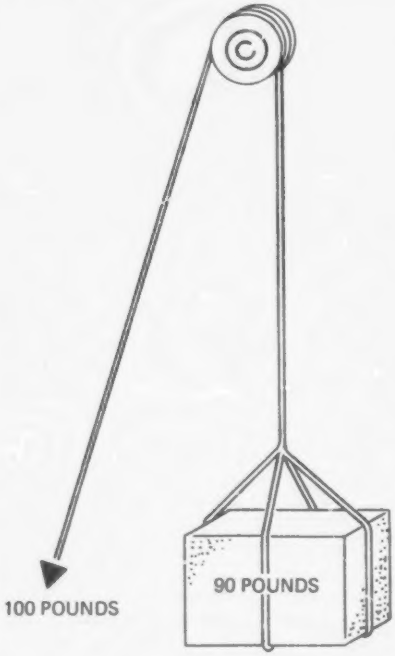


Figure 2-66. Pulley System with a 90-Percent Efficiency.

The engine also is subject to many power losses. The two categories of losses are thermal and mechanical. The overall efficiency of an engine will be calculated in the next three paragraphs.

2-38. Thermal Efficiency. Thermal efficiency is the relationship between actual heat energy stored within the fuel and the power produced in the engine (indicated horsepower). The thermal efficiency figure indicates how much of the potential energy contained in the fuel actually is used by the engine to produce power and how much energy is lost through heat. There is an extremely large amount of energy from the fuel that is lost through heat in an internal combustion engine. This unused heat that is produced while the engine is producing power is of no value to the engine and must be removed from it.

a. The heat is dissipated in the following ways.

(1) The cooling system removes heat from the engine to control engine operating temperature.

(2) A major portion of the heat produced by the engine exits through the exhaust system.

(3) The engine radiates a portion of the heat to the atmosphere.

(4) A portion of this waste heat may be channeled to the passenger compartment to heat it.

(5) The lubricating oil in the engine removes a portion of the waste heat.

b. In addition to energy lost through wasted heat, there are the following inherent losses in the piston engine.

(1) Much energy is consumed when the piston must compress the mixture on the compression stroke.

(2) Energy from the gasoline is consumed to pull the intake mixture into the cylinder.

TA233350

(3) Energy from the gasoline is consumed to push the exhaust gases out of the cylinder.

c. The combination of all of the factors in a piston engine that use and waste energy leaves the average engine approximately 20 to 25 percent thermally efficient. To calculate the thermal efficiency, the potential energy in the gasoline and the indicated horsepower must be expressed in a common unit of measure. Both of these factors may be converted to British thermal units (Btu). The conversion factors are:

$$\text{One Btu} = 778 \text{ ft lb of work.}$$

$$\text{Energy value of 1 lb of gas} = 18{,}800 \text{ Btu.}$$

For example: A given engine delivers 90 indicated horsepower for a period of 1 hour, and in that time consumes 50 lb (7 1/2 gal.) of gasoline. Given this data, the thermal efficiency of the engine can be calculated by doing the following:

(1) Calculate how many Btu's of work are performed by 1 hp in 1 hour by doing the following:

$$1 \text{ hp hr} = \frac{33{,}000 \text{ ft lb per minute} \times 60 \text{ minutes}}{778 \text{ ft lb per Btu}} = 2445 \text{ Btu.}$$

(2) Calculate the Btu's of work output for 90 hp hr using the information from (1) by doing the following:

$$2445 \text{ Btu's} \times 90 = 22{,}050 \text{ Btu's.}$$

(3) Calculate how many Btu's were inputted by doing the following:

$$18{,}800 \text{ Btu's} \times 50 \text{ lb} = 940{,}000 \text{ Btu's input per hour.}$$

(4) Calculate the thermal efficiency by doing the following:

$$\frac{\text{Indicated horsepower (Btu's)}}{\text{Fuel input (Btu's)}} = \frac{22{,}050}{940{,}000} = 0.23 \times 100 = 23 \text{ percent.}$$

2-39. Mechanical Efficiency. Mechanical efficiency within the engine is the relationship between the actual power produced in the engine (indicated horsepower) and the actual power delivered at the crankshaft (brake or shaft horsepower). The actual power at the crankshaft is always less than the power produced within the engine. This is due to the following:

a. Frictional losses between the many moving parts.

b. In four-stroke cycle engines, a great deal of horsepower is used to drive the valve train. Mechanical efficiency is calculated by dividing the brake or shaft horsepower by the indicated horsepower. For example: When checked on a dynamometer, the engine with the indicated horsepower of 90, referred to in paragraph 2-38, produces a brake horsepower of 85. To calculate the mechanical efficiency, do the following:

$$\text{Mechanical efficiency} = \frac{\text{brake horsepower}}{\text{indicated horsepower}} \times 100 = \frac{85}{90} = 94 \text{ percent.}$$

2-40. Overall Efficiency. In paragraphs 2-38 and 2-39, the thermal and mechanical losses of the engine were calculated. Use the following procedure to calculate the overall efficiency of the engine. The overall efficiency is the relationship between the power input and the true output of the engine (brake or shaft horsepower). The input will be expressed, as in paragraph 2-38, in Btu's. The power output also must be converted to Btu's. Begin by using the information calculated in paragraph 2-38b:

Total power input = 940,000 Btu's per hour.
1 hp hr = 2,445 Btu's.

The overall efficiency then is calculated by using the following procedures.

a. Calculate the work output in Btu's for 85 horsepower-hours by doing the following:

85 hp x 2445 Btu's = 207,825 Btu's.

b. Calculate the overall efficiency by doing the following:

$$\frac{\text{Brake horsepower}}{\text{Fuel input}} = \frac{\text{207,825 Btu's}}{\text{940,000 Btu's}} =$$

0.22 x 100 = 22 percent.

CHAPTER 3

CONVENTIONAL ENGINE CONSTRUCTION

Section I. CYLINDER BLOCKS, HEADS, AND CRANKCASES

3-1. Cylinder Blocks – Liquid-Cooled Engines.

a. General (Fig. 3-1). The cylinder, or the engine block, is the basic foundation of virtually all liquid-cooled engines. The block is a solid casting made of cast iron or aluminum that contains the crankcase, cylinders, coolant passages, and, in the case of flathead engines, the valve seats, ports, and guides.

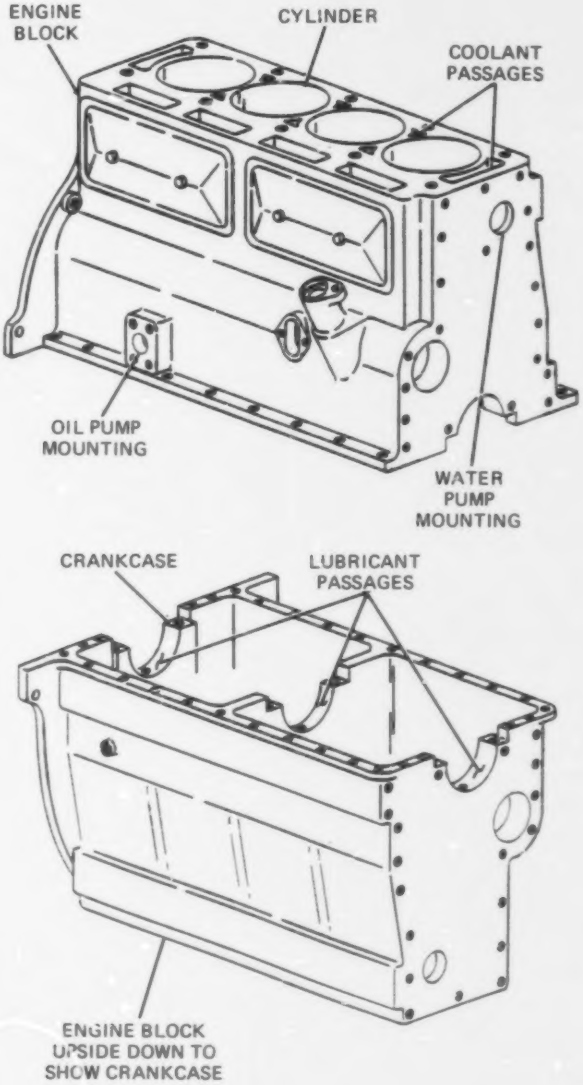


Figure 3-1. Liquid-Cooled Cylinder Block.

TA233351

b. Construction. The cylinder block is a one-piece casting that is usually an iron alloy containing nickel and molybdenum. This is the best overall material for cylinder blocks. It provides excellent wearing qualities, low material and production costs, and it only changes dimensions minimally when heated. Another material that is used for cylinder blocks, although not extensively, is aluminum. Aluminum is used whenever weight is a consideration. It is not as practical to use for the following reasons:

(1) Aluminum is more expensive than cast iron.

(2) Aluminum is not as strong as cast iron.

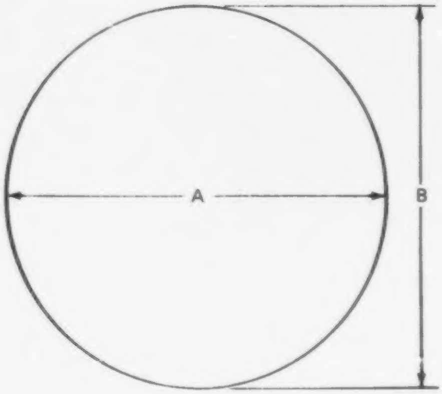
(3) Due to the softness of aluminum, it cannot be used on any surface of the block that is subject to wear. This necessitates the pressing, or casting, of steel sleeves into the cylinder bores. Threaded holes must be deeper, which introduces extra design considerations. All of these things increase production costs.

(4) Aluminum has a much higher expansion rate than iron when heated. This creates problems with maintaining tolerances.

c. Cylinders (Fig. 3-2). The cylinders are bored right into the block. A good cylinder must be round, not varying in diameter by more than approximately 0.0005 in. (0.012 mm). The diameter of the cylinder also must be uniform for its entire length.

d. Cylinder Sleeves (Fig. 3-3). Cylinder sleeves or liners commonly are used to provide a wearing surface other than the cylinder block for the pistons to ride against. This is important for the following reasons:

(1) Alloys of steel can be used that will wear longer than the surfaces of the cylinder block.



A AND B MUST NOT
VARY MORE THAN 0.0005 IN.

Figure 3-2. Requirements of a Cylinder.

This will increase engine life while keeping production costs down.

(2) Because the cylinders wear more than any other area of the block, the life of the block can be extended greatly by using sleeves. When overhaul time comes, the block then can be renewed by merely replacing the sleeves. For this reason, sleeves are very popular in large diesel engines, for which the blocks are very expensive.

(3) As stated in paragraph 3-1b, using a sleeve allows an engine to be made of a material such as aluminum by providing the wearing qualities necessary for the cylinder that the aluminum cannot.

There are two types of cylinder sleeves: the wet and the dry type. The dry type is a sleeve that presses into a full cylinder that completely covers the water jacket. Because the sleeve has the block to support it, it can be very thin. The wet sleeve also presses into the cylinder. The difference is that the water jacket is open in the block and is completed by the sleeve. Because it gets no central support from the block, the wet sleeve must be made thicker than a dry sleeve. Also, because the sleeve completes the water jacket, it must fit so as to seal in the coolant. The following are the three basic ways of securing the sleeves in the cylinder block:

(1) Pressing in a sleeve that is tight enough to be held in by friction.

(2) Providing a flange at the top of the block that locks the sleeve in place when the cylinder head is bolted into place. This is more desirable than a friction fit, because it locks the sleeve tightly.

(3) Casting the sleeve into the cylinder wall. This is a popular means of securing the sleeve in an aluminum block.

Whatever method is used to secure the sleeve, it is very important that the sleeve fits tightly. This is important so that the sleeve may transfer its heat effectively to the water jackets.

e. Crankcase (Fig. 3-4). The crankcase is the part of the cylinder block that supports and encloses the crankshaft. It is also where the engine's lubricating oil is stored. The upper part of the crankcase usually is part of the cylinder block, while the lower part is removable. This removable lower part usually is called an oil pan, and is made of cast aluminum or pressed steel.

f. Cooling and Lubrication (Fig. 3-1). The cylinder block also provides the foundation for the cooling and the lubrication systems. It provides the mountings for the pumps, and has the coolant and lubrication passages cast into it.

3-2. Cylinder Heads.

a. General (Fig. 3-5). The cylinder head is a separate one-piece casting that bolts to the top of the cylinders on an air-cooled engine, or to the top of the cylinder block on a liquid-cooled engine.

b. Construction.

(1) The cylinder heads on liquid-cooled engines have been made almost exclusively from cast iron until recent years. Due to weight considerations that have become more important, a large percentage of cylinder heads now are being made from aluminum.

(2) The cylinder heads on air-cooled engines are made almost exclusively from aluminum. This is due to the fact that aluminum will conduct heat approximately three times as fast as cast iron. This is a critical consideration with air cooling.

TA233352

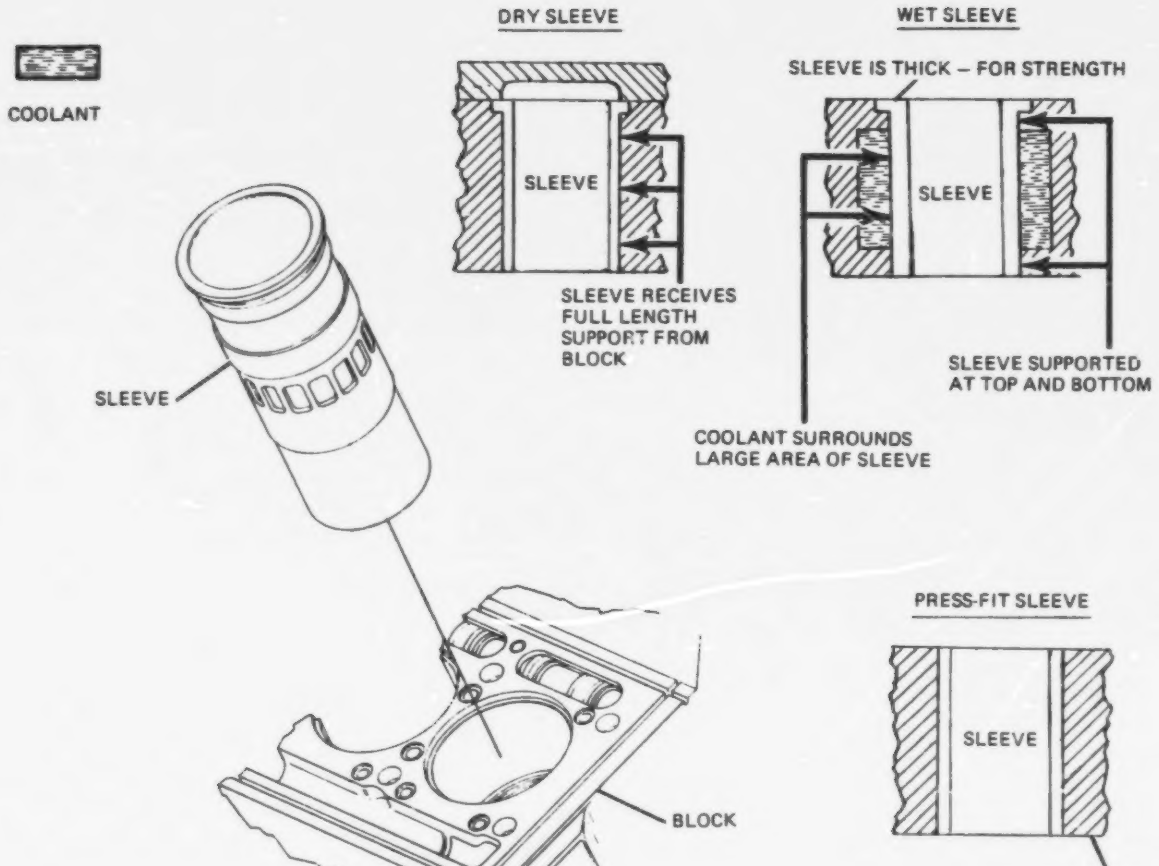

COOLANT
DRY SLEEVE
SLEEVE
SLEEVE RECEIVES FULL LENGTH SUPPORT FROM BLOCK
WET SLEEVE
SLEEVE IS THICK – FOR STRENGTH
SLEEVE
SLEEVE SUPPORTED AT TOP AND BOTTOM
COOLANT SURROUNDS LARGE AREA OF SLEEVE
SLEEVE
BLOCK
PRESS-FIT SLEEVE
SLEEVE
BLOCK
CYLINDER HEAD
SLEEVE HELD IN PLACE BY HEAD PRESSING ON FLANGE
FLANGED SLEEVE
BLOCK METAL IS CAST AROUND SLEEVE
SLEEVE
CAST-IN SLEEVE

Figure 3-3. Cylinder Sleeves.

TA233353

47

BEST COPY AVAILABLE

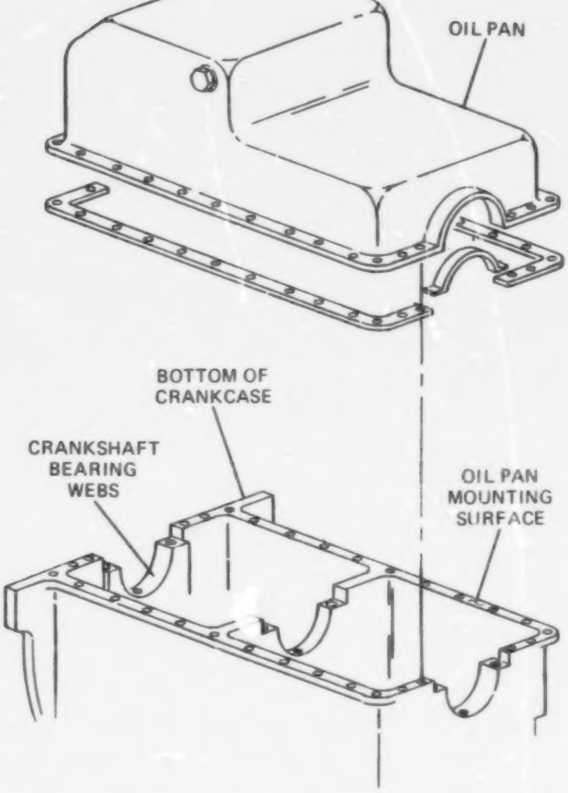


Figure 3-4. Engine Crankcase.

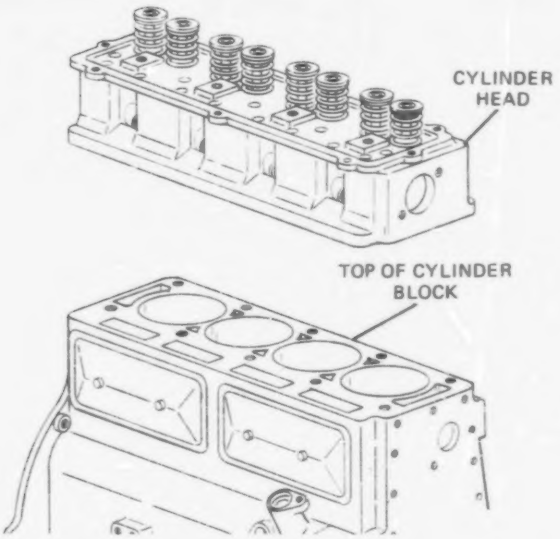


Figure 3-5. Typical Cylinder Head Installation.

c. Combustion Chambers (Fig. 3-6). The cylinder head seals the end of the cylinder. This serves to provide a combustion chamber for the ignition of the mixture and to hold the expansive forces of the burning gases so that they may act on the piston. There is a threaded hole to position the spark plug in the combustion chamber on gasoline engines. On diesel engines there is a similar arrangement to position the fuel injector.

d. Valves and Ports (Fig. 3-7). The cylinder head on overhead valve configurations supports the valves and has the ports cast into it. The cylinder head on overhead camshaft configurations also supports the camshaft.

e. Cooling.

(1) Cylinder heads on air-cooled configurations (A, fig. 3-8) have fins cast into their outer surfaces.

(2) Cylinder heads on liquid-cooled configurations (B, fig. 3-8) have passages for coolant flow cast into them.

f. Sealing.

(1) Cylinder heads on air-cooled configurations (A, fig. 3-9) are sealed to the tops of the cylinders by soft metal rings. The lubrication system usually feeds oil to the heads through the pushrods.

(2) Cylinder heads on liquid-cooled configurations (B, fig. 3-9) are sealed to the cylinder block by the head gasket. The head gasket usually is made of two sheets of soft steel that sandwich a layer of asbestos. Steel rings are used to line the cylinder openings. They are to hold the tremendous pressures created on the power stroke. Holes are cut in the gasket to mate the coolant and lubrication feed holes between the cylinder block and the cylinder head.

3-3. Cylinders – Air-Cooled Engines (Fig. 3-10). The cylinders on air-cooled engines are separate from the crankcase. They usually are made of forged steel. This material is most suitable for cylinders because of its excellent wearing qualities, and its ability to withstand the high temperatures that air-cooled cylinders do obtain. The cylinders have rows of deep fins cast into them to dissipate engine heat. The cylinders

TA233354

48

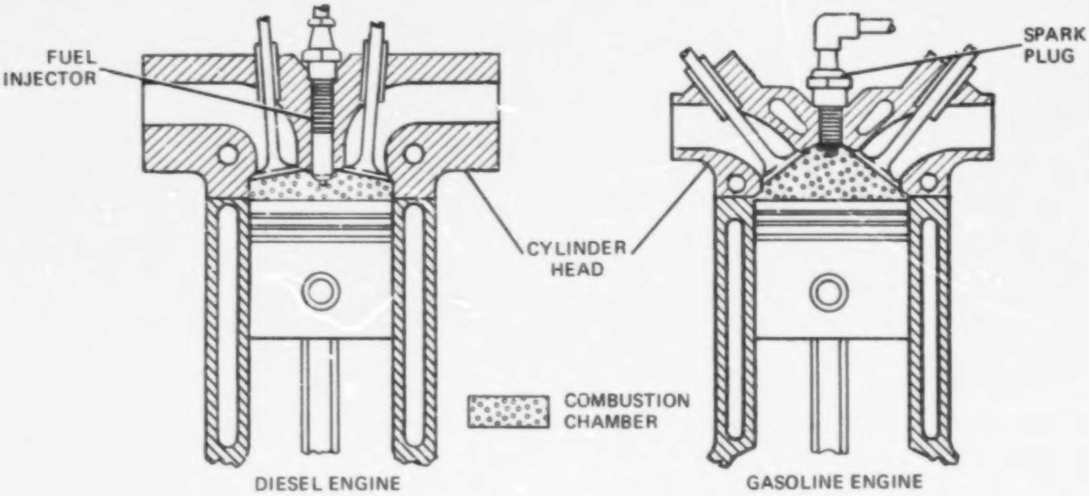


Figure 3-6. Combustion Chambers.

commonly are mounted by securing the cylinder head to the crankcase with long studs, and sandwiching the cylinders between the two. Another way of mounting the cylinders is to bolt them to the crankcase, and then secure the heads to the cylinders.

3-4. Crankcase – Air-Cooled Engines.

a. General (Fig. 3-11). The crankcase is the basic foundation of all air-cooled engines. It is made as a one- or two-piece casting that supports the crankshaft, provides the mounting surface for the cylinders and the oil pump, and has the lubrication passages cast into it.

b. Construction (Fig. 3-11). Crankcases in air-cooled engines are made of aluminum because it has the ability to dissipate large quantities of heat. There is usually a removable lower half to the crankcase that holds the reservoir of lubricating oil. It commonly is referred to as the oil pan. On air-cooled engines, the oil pan usually is cast aluminum. Its surface is covered with fins. The oil pan on an air-cooled engine plays a key role in the removal of waste heat from the engine through its lubricating oil.

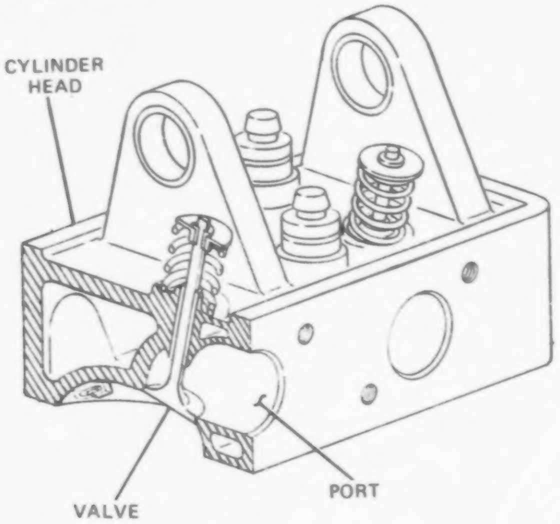
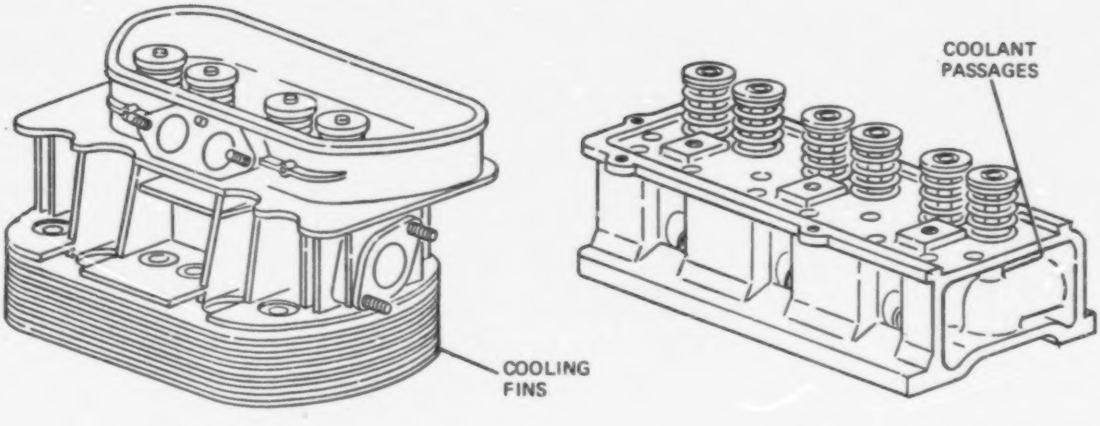


Figure 3-7. Valves and Ports.

TA233355

49

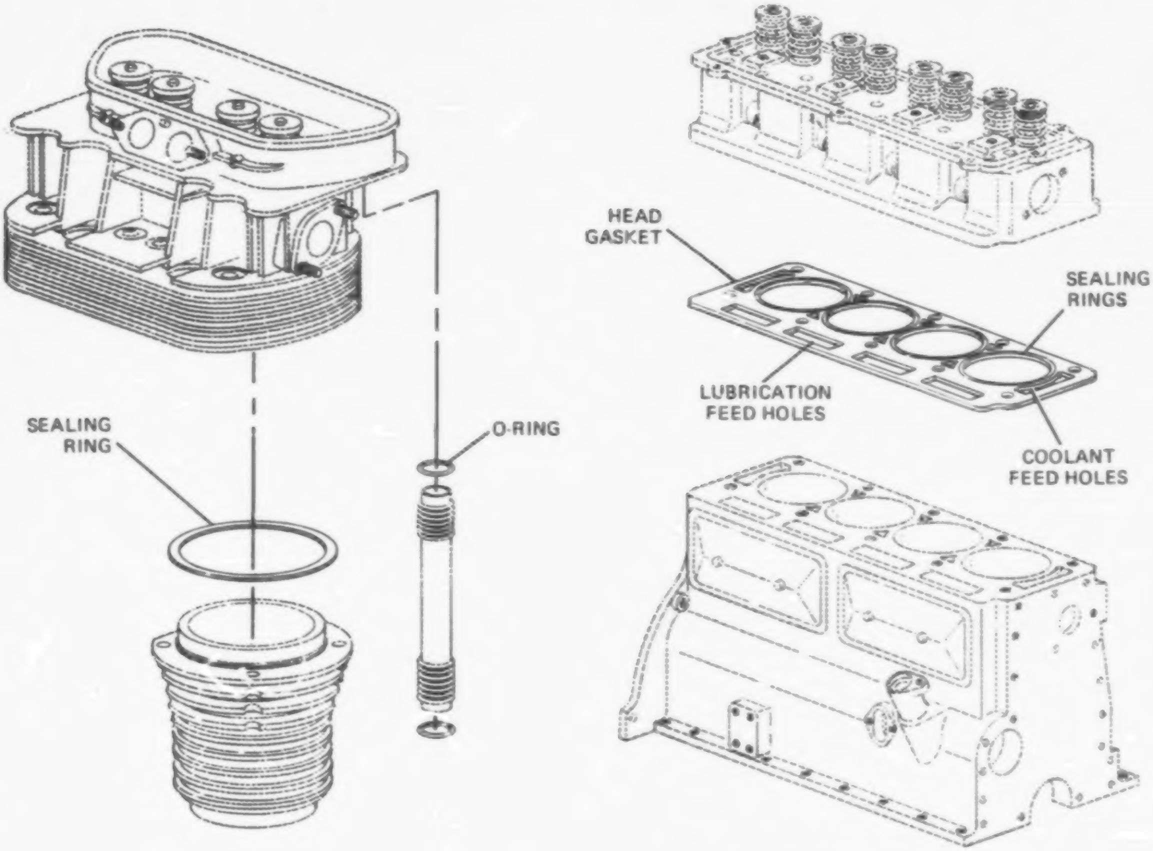
BEST COPY AVAILABLE


COOLANT
PASSAGES
COOLING
FINS

A. AIR COOLED

B. LIQUID COOLED

Figure 3-8. Cylinder Head Cooling.


HEAD
GASKET
SEALING
RINGS
LUBRICATION
FEED HOLES
COOLANT
FEED HOLES
SEALING
RING
O-RING

A. AIR COOLED

B. LIQUID COOLED

Figure 3-9. Cylinder Head Sealing.

TA233356

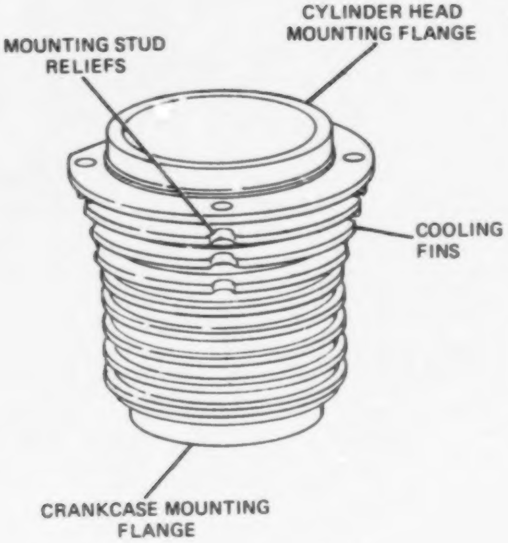

CYLINDER HEAD MOUNTING FLANGE
MOUNTING STUD RELIEFS
COOLING FINS
CRANKCASE MOUNTING FLANGE

Figure 3-10. Air-Cooled Cylinder.

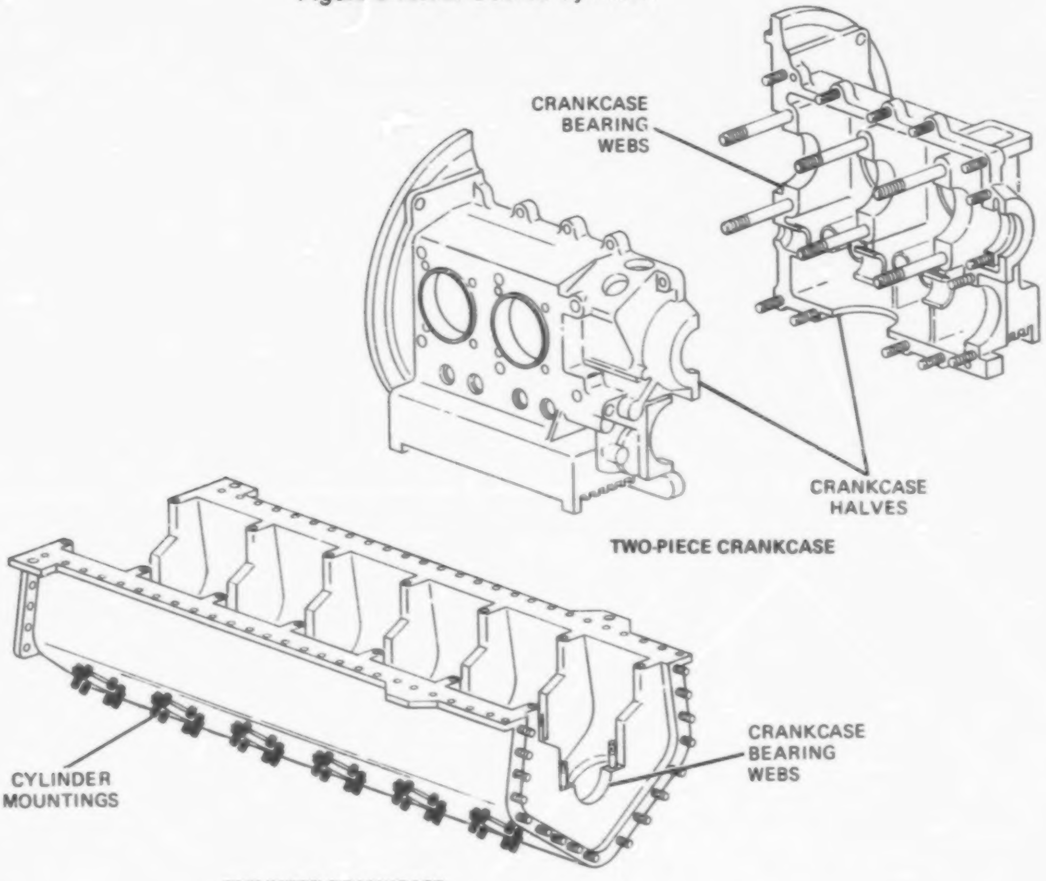

CRANKCASE BEARING WEBS
CRANKCASE HALVES
TWO-PIECE CRANKCASE
CRANKCASE BEARING WEBS
CYLINDER MOUNTINGS
ONE-PIECE CRANKCASE

Figure 3-11. Air-Cooled Crankcase.

TA233357

51

BEST COPY AVAILABLE

Section II. ROTATING AND RECIPROCATING PARTS

3-5. Piston.

a. General (Fig. 3-12). The piston is the part of the engine that receives the energy from the combustion and transmits it to the crankshaft.

b. Requirements (Fig. 3-12). The piston must withstand incredible punishment under severe temperature extremes. The following are examples of conditions that a piston must withstand at normal highway speeds.

(1) As the piston moves from the top of the cylinder to the bottom (or vice versa), it accelerates from a stop to a speed of approximately 50 mph (80 km/h) at midpoint, and then decelerates to a stop again. It does this approximately 80 times per second.

(2) The piston is subjected to pressures on its head in excess of 1000 psi (6895 kPa).

(3) The piston head is subjected to temperatures well over 600°F (316°C).

c. Construction Materials. When designing pistons, weight is a major consideration. This is because of tne tremendous inertial forces created by the rapid change in piston direction. For this reason, it has been found that aluminum is the best material for piston construction. It has a very high strength-to-weight ratio. In addition to being lightweight, aluminum is an excellent conductor of heat and is machined easily. Pistons also are manufactured from cast iron. Cast iron also is an excellent material for pistons in low-speed engines. It is not suitable for high speeds because it is a very heavy material.

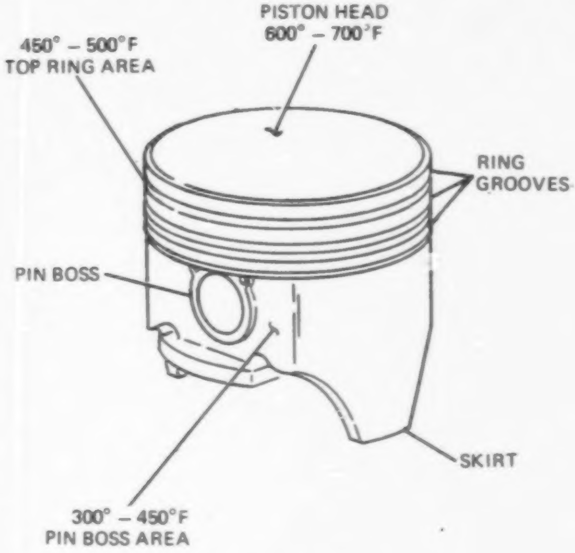


Figure 3-12. Piston.

d. Controlling Expansion (Fig. 3-13). Pistons must have features built into them to help them control expansion. Without these features, pistons would fit loosely in the cylinders when cold, and then bind in the cylinders as they warm up. This is a problem with aluminum, because it expands so much. To control expansion, pistons may be designed with the following features:

(1) It is obvious that the crown of the piston will get hotter than the rest of the piston. To prevent it from expanding to a larger size than the rest of the piston, it is machined to a diameter that is approximately 0.03 to 0.04 in. (0.762 to 1.016 mm) smaller than the skirt area.

(2) One of the ways to control expansion in the skirt area is to cut a slot up the side of the skirt. As a split-skirt piston warms up, the split will merely close up, thereby keeping the skirt from expanding outward and binding the piston in the cylinder.

(3) Another variation of the split-skirt piston is the T-slot piston. The T-slot piston is similar to the split-skirt piston with the addition of a horizontal slot that retards heat transfer from the piston head to the piston skirt.

(4) Some aluminum pistons have steel braces cast into them to control expansion.

e. Cam Grinding (Fig. 3-14). By making the piston egg-shaped, it will be able to fit the cylinder better throughout its operational temperature range. A piston of this configuration is called a cam-ground piston. Cam-ground pistons are machined so that their diameter is smaller parallel to the piston pin axis than it is perpendicular to it. When the piston is cold, it will be big enough

TA233358

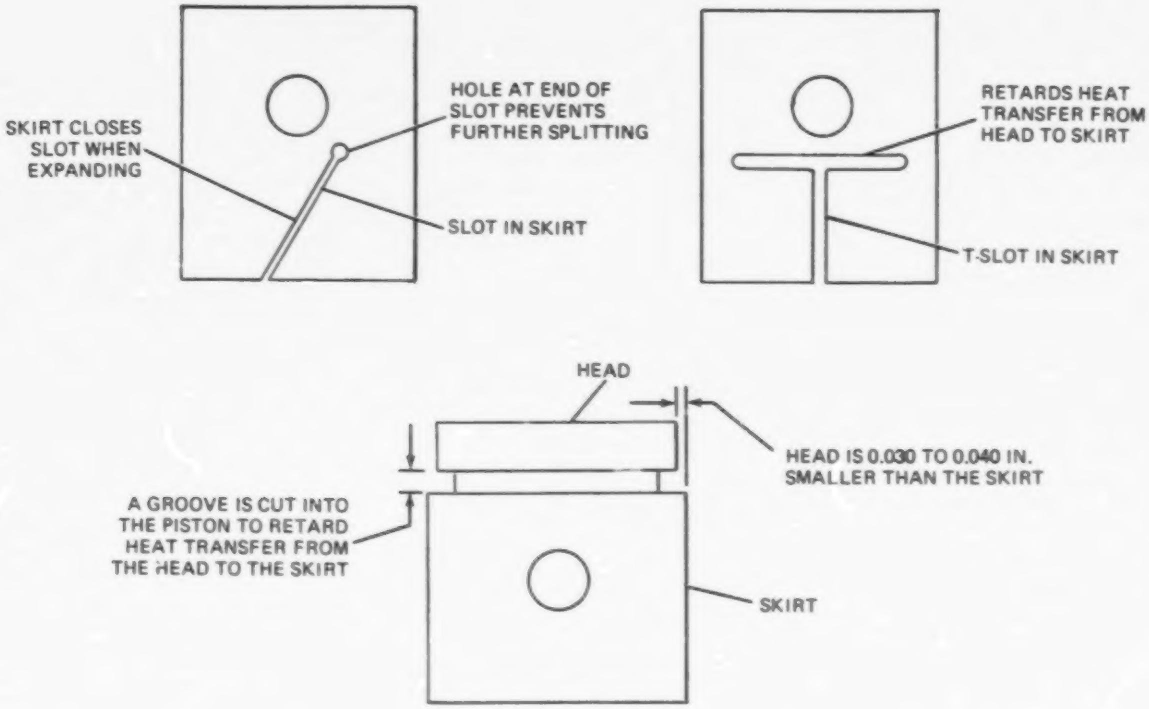

SKIRT CLOSES SLOT WHEN EXPANDING
HOLE AT END OF SLOT PREVENTS FURTHER SPLITTING
SLOT IN SKIRT
RETARDS HEAT TRANSFER FROM HEAD TO SKIRT
T-SLOT IN SKIRT
HEAD
HEAD IS 0.030 TO 0.040 IN. SMALLER THAN THE SKIRT
A GROOVE IS CUT INTO THE PISTON TO RETARD HEAT TRANSFER FROM THE HEAD TO THE SKIRT
SKIRT

Figure 3-13. Controlling Piston Expansion.

across the larger diameter to keep from rocking. As it warms up, it will expand across its smaller diameter at a much higher rate than at its larger diameter. This will tend to make the piston round at operating temperature. Virtually all pistons in automotive applications are cam ground.

f. Partial-Skirted (Slipper-Skirt) Pistons (Fig. 3-15). The purpose of the piston skirt is to keep the piston from rocking in the cylinder. The slipper-skirt piston has large portions of its skirt removed in the nonthrust aras. Removal of the skirt in these areas serves the following purposes:

(1) Lightens the piston, which, in turn, increases the speed range of the engine.

(2) Reduces the contact area with the cylinder wall, which reduces friction.

(3) Allows the piston to be brought down closer to the crankshaft without interference with its counterweights.

g. Strength and Structure (Fig. 3-16). When designing a piston, weight and strength are both

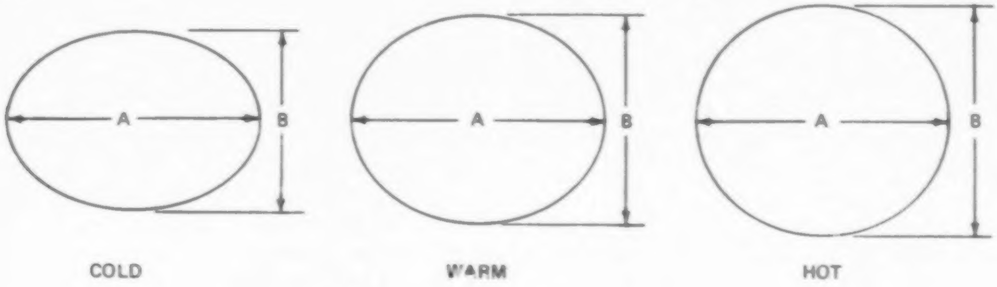
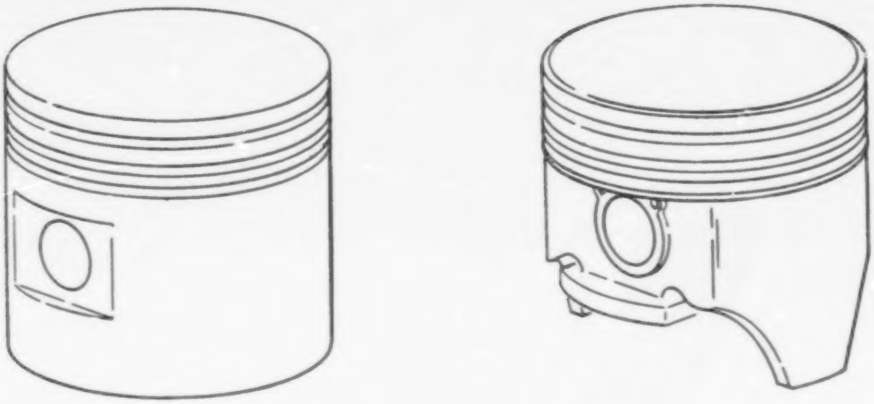

A
B
COLD
WARM
HOT

Figure 3-14. Cam-Ground Piston.

TA233359


FULL-SKIRTED PISTON

PARTIAL-SKIRTED PISTON

Figure 3-15. Full- and Partial-Skirted Pistons.

critical factors. Two of the ways pistons are made strong and light are as follows:

(1) The head of the piston is made as thin as is practical. To keep it strong enough, there are ribs cast into the underside of it.

(2) The areas around the piston pin are reinforced. These areas are called the pin bosses.

h. Coatings. Pistons that are made from aluminum usually are treated on their outer surfaces to aid in engine break-in and increase hardness. The following are the most common processes for treatment of aluminum pistons.

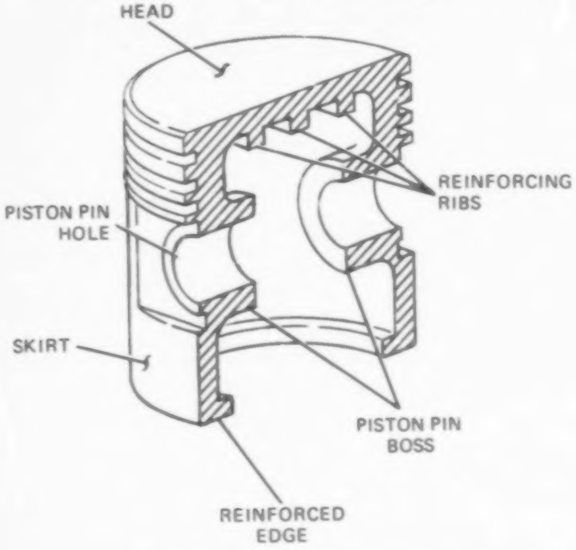


Figure 3-16. Piston Structure.

(1) The piston is coated with tin so that it will work into the cylinder walls as the engine is broken in. This process results in a more perfect fit, shortening of the break-in period, and an increase in overall engine longevity.

(2) The piston is anodized to produce a harder outside surface. Anodizing is a process that produces a coating on the surface by electrolysis. The process hardens the surface of the piston. This helps it resist picking up particles that may become embedded in the piston, causing cylinder wall damage.

3-6. Piston Rings.

a. General (Fig. 3-17). Piston rings serve three important functions:

(1) They provide a seal between the piston and the cylinder wall to keep the force of the exploding gases from leaking into the crankcase from the combustion chamber. This leakage is referred to as blowby. Blowby is detrimental to engine performance because the force of the exploding gases will merely bypass the piston rather than push it down. It also contaminates the lubricating oil.

(2) They keep the lubricating oil from bypassing the piston and getting into the combustion chamber from the crankcase.

TA233360

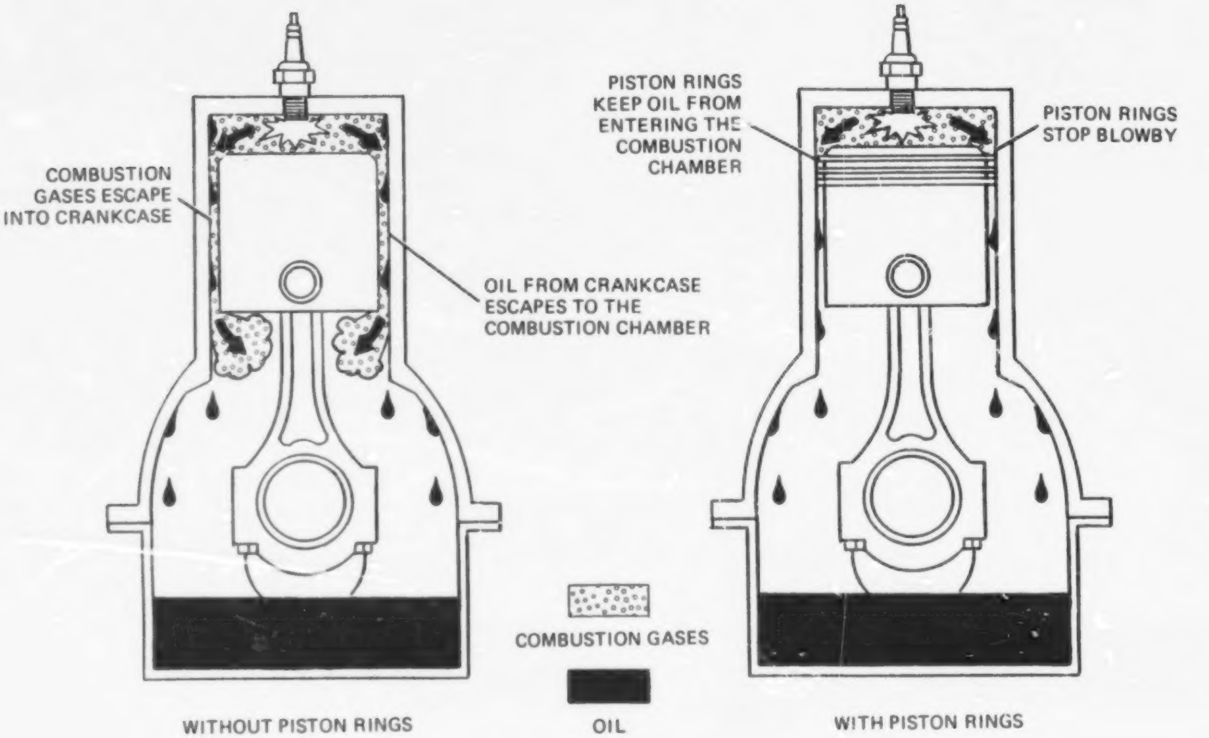

COMBUSTION GASES ESCAPE INTO CRANKCASE
OIL FROM CRANKCASE ESCAPES TO THE COMBUSTION CHAMBER
PISTON RINGS KEEP OIL FROM ENTERING THE COMBUSTION CHAMBER
PISTON RINGS STOP BLOWBY
COMBUSTION GASES
OIL
WITHOUT PISTON RINGS
WITH PISTON RINGS

Figure 3-17. Purpose of Piston Rings.

(3) They provide a solid bridge to conduct the heat from the piston to the cylinder wall. About one-third of the heat absorbed by the piston passes to the cylinder wall through the piston rings.

b. *Description (Fig. 3-18).* Piston rings are secured on the pistons by fitting into grooves. They are split to allow for installation and expansion, and they exert an outward pressure on the cylinder wall when installed. They fit into grooves that are cut into the piston, and are allowed to float freely in these grooves. A properly formed piston ring, working in a cylinder that is within limits for roundness and size, will exert an even pressure and a solid contact with the cylinder wall around its entire circumference. There are two basic classifications of piston rings.

(1) *The Compression Ring.* The compression ring seals the force of the exploding mixture into the combustion chamber.

(2) *The Oil Control Ring.* The oil control ring keeps the engine's lubricating oil from getting into the combustion chamber.

c. *Configurations.* Piston rings are arranged on the pistons in three basic configurations. They are:

(1) The three-ring piston (A, fig. 3-19) that has two compression rings from the top, followed by one oil control ring. This is the most common piston ring configuration.

(2) The four-ring piston (B, fig. 3-19) that has three compression rings from the top, followed by one oil control ring. This configuration is common in diesel engines because they are more prone to blowby. This is due to the much higher pressures generated during the power stroke.

(3) The four-ring piston (C, fig. 3-19) that has two compression rings from the top, followed by two oil control rings. The bottom oil control ring may be located above or below the piston pin. This is not a very common configuration in current engine design.

TA233361

55

BEST COPY AVAILABLE

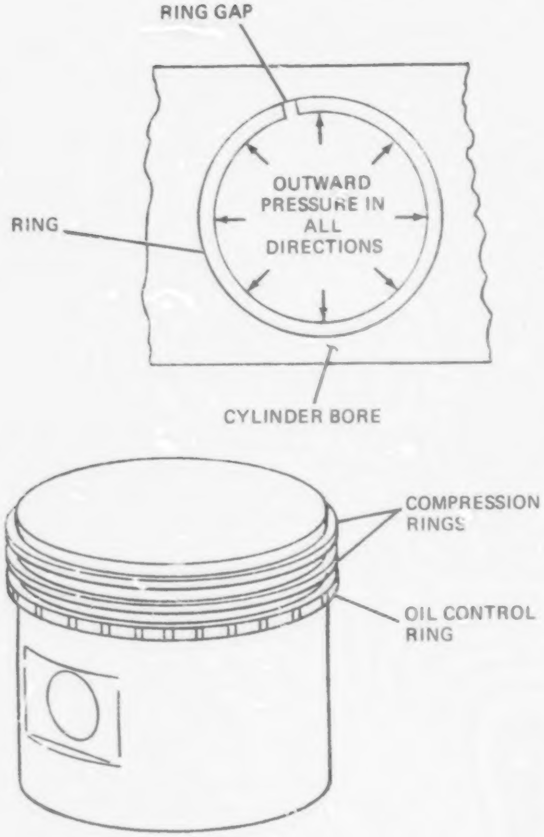


Figure 3-18. Piston Ring Types and Description.

In addition to the configurations mentioned previously, there are some diesel engines that use five or more piston rings on each piston to control the higher operating pressures.

d. Compression Ring. As stated in paragraph 3-6b, the purpose of the compression ring is to hold the pressure from the power stroke in the combustion chamber. There are many different cross sectional shapes of piston rings available (fig. 3-20).

The various shapes of rings all serve to preload the ring so that its lower edge presses against the cylinder wall. As shown in figure 3-21, this serves the following functions:

(1) The pressure from the power stroke will force the upper edge of the ring into contact with the cylinder wall, forming a good seal.

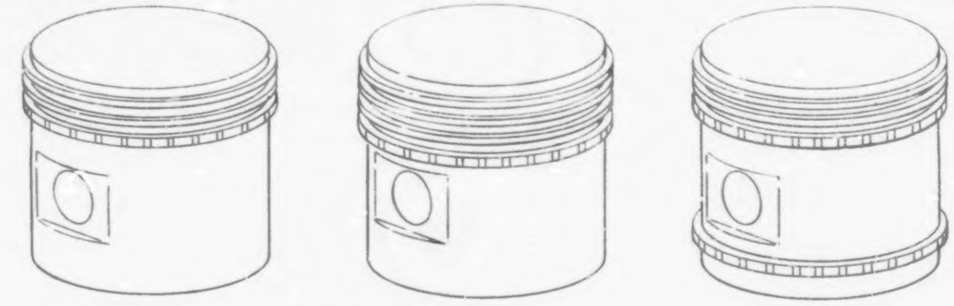
(2) As the piston moves downward, the lower edge of the ring scrapes, from the cylinder walls, any oil that manages to work past the oil control rings.

(3) On the compression and the exhaust strokes, the ring will glide over the oil, increasing its life.

e. Heat Dam (Fig. 3-22). There is an additional groove cut in the piston just above the top ring groove. The purpose of it is to divert some of the intense heat that is absorbed by the piston head away from the top ring. The groove is called a heat dam.

f. Ring Gap. The split in the piston ring is necessary for:

(1) Installing the ring on the piston.



A. THREE RING

TWO COMPRESSION RINGS
ONE OIL CONTROL RING

B. FOUR RING

THREE COMPRESSION RINGS
ONE OIL CONTROL RING

C. FOUR RING

TWO COMPRESSION RINGS
TWO OIL CONTROL RINGS

Figure 3-19. Configurations of Piston Rings.

TA233362

56

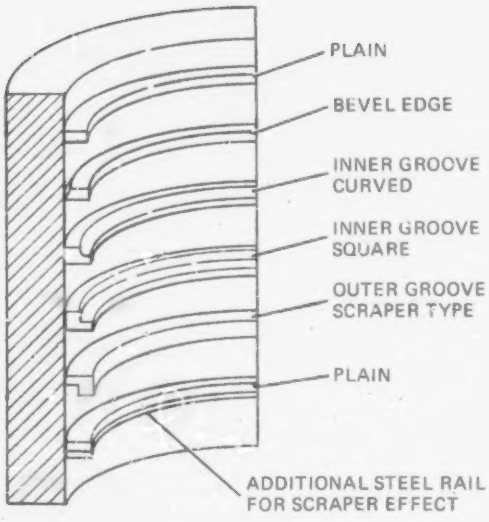

PLAIN
BEVEL EDGE
INNER GROOVE CURVED
INNER GROOVE SQUARE
OUTER GROOVE SCRAPER TYPE
PLAIN
ADDITIONAL STEEL RAIL FOR SCRAPER EFFECT

Figure 3-20. Types of Compression Rings.

(2) Allowing for expansion from heating.

The gap must be such that there is enough space so that the ends do not come together as the ring heats up. This would cause the ring to break. This is illustrated in figure 3-23.

There are a few variations of ring gap joints (fig. 3-24). Two cycle engines usually have pins in their ring grooves to keep the gap from turning. This is important because the ring would break if the ends were allowed to snap into the inlet or the exhaust ports.

g. Second Compression Ring (Fig. 3-25). The primary reason for using a second compression ring is to hold back any blowby that may have occurred at the top ring. A significant amount of the total blowby at the top ring will be from the ring gap. For this reason, the top and the second compression rings are assembled to the piston with their gaps 60 degrees offset with the first ring gaps.

h. Top Ring Groove Insert (Fig. 3-26). The top ring groove is very vulnerable to wear for the following reasons:

(1) It is close to the piston head, subjecting it to intense heat.

(2) The top compression ring is exposed directly to the high pressures of the compression stroke.

To remedy the potential problem of premature top ring groove wear, some aluminum pistons are fitted with an insert in the top ring groove. The insert usually is made from nickel iron. Because of the better wear qualities, the ring groove will last longer than if the ring fit directly against the aluminum.

i. Oil Control Rings (Fig. 3-27). The oil control rings serve to control the lubrication of the cylinder walls. They do this by scraping the excess oil from the cylinder walls on the downstroke. The oil then is forced through slots in the piston ring and the piston ring groove. The oil then drains back into the crankcase. The rings are made in many different configurations that can be one-piece units or multipiece assemblies. Regardless of the configuration, all oil control rings work basically in the same way.

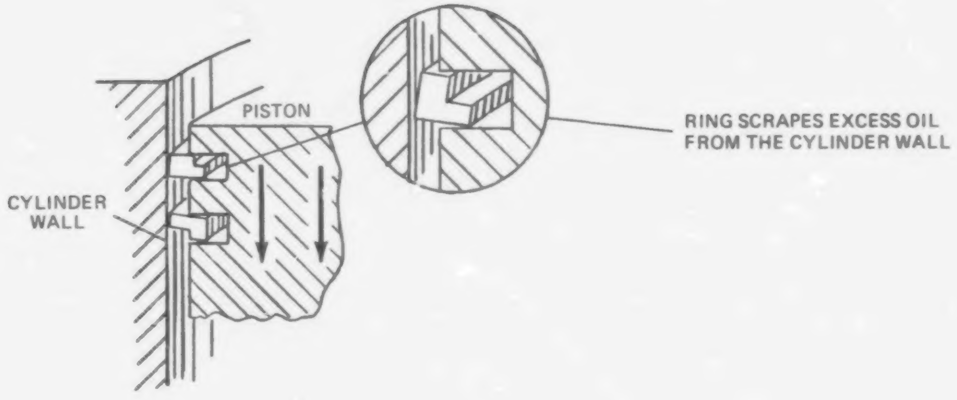
j. Piston Ring Expanders (Fig. 3-28). Expander devices are used in some applications. These devices fit behind the piston ring and force it to fit tighter to the cylinder wall. They are particularly useful in engines where a high degree of cylinder wall wear exists.

k. Piston Ring Wear-In (Fig. 3-29). When piston rings are new, a period of running is necessary to wear the piston rings a small amount so that they will conform perfectly to the cylinder walls. To make the job of wearing in the piston rings more effective and quicker, the following procedures are performed.

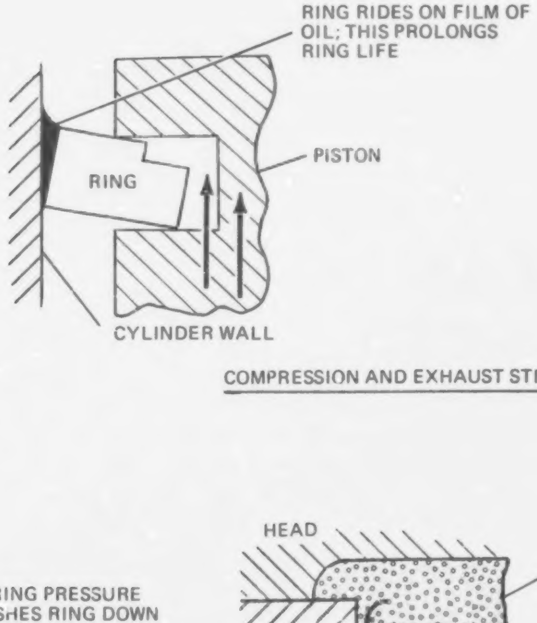
(1) The cylinder walls are surfaced with a tool called a hone. The hone leaves fine scratches in the cylinder walls. The piston rings are made with grooves in their faces. The grooved faces of the piston rings rubbing against the roughened cylinder walls serve to accelerate ring wear during the initial stages, and speed wear-in. As the surfaces wear smooth, the rings will be worn in.

(2) Extreme pressure may be applied to high spots on the piston rings during the wear-in period. This can cause the piston rings to

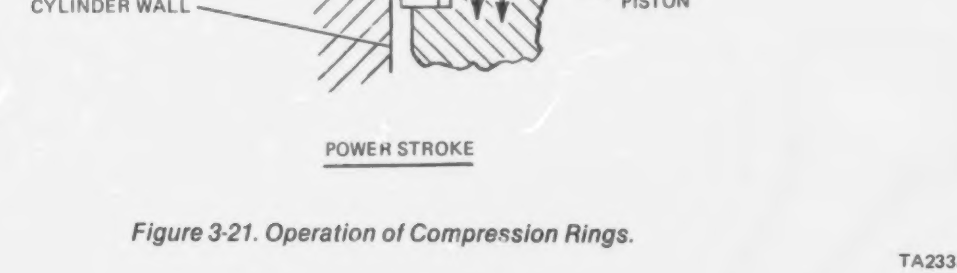
TA233363


PISTON
RING SCRAPES EXCESS OIL FROM THE CYLINDER WALL
CYLINDER WALL

INTAKE STROKE


RING RIDES ON FILM OF OIL; THIS PROLONGS RING LIFE
PISTON
RING
CYLINDER WALL

COMPRESSION AND EXHAUST STROKES


HEAD
FIRED FUEL MIX
▨ FUEL & AIR MIX
FIRING PRESSURE PUSHES RING DOWN UNTIL ENTIRE RING FACE ENGAGES CYLINDER WALL
CYLINDER WALL
PISTON

POWER STROKE

Figure 3-21. Operation of Compression Rings.

TA233364

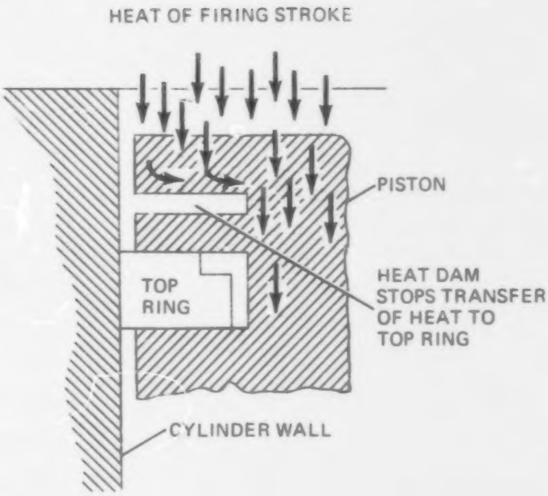

HEAT OF FIRING STROKE
PISTON
TOP RING
HEAT DAM STOPS TRANSFER OF HEAT TO TOP RING
CYLINDER WALL

Figure 3-22. Heat Dam.

overheat at these points and cause damage to the cylinder walls in the form of rough streaks. This condition is called scuffing. New piston rings are coated with a porous material such as graphite, phosphate, or molybdenum. These materials absorb oil and serve to minimize scuffing. As the rings wear in, the coatings wear off.

(3) Some piston rings are chrome plated. Chrome-plated rings generally provide better overall wearing qualities. They also are finished to a greater degree of accuracy, which lets them wear in faster.

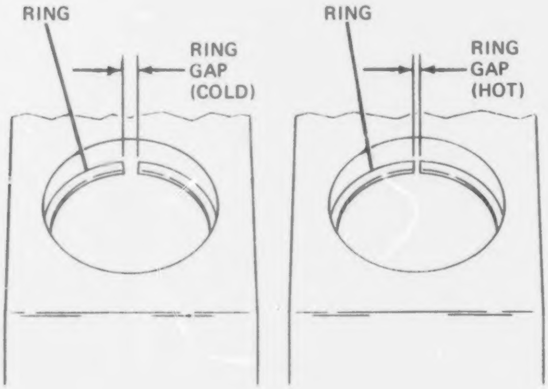

RING
RING GAP (COLD)
RING
RING GAP (HOT)

Figure 3-23. Ring Gap.

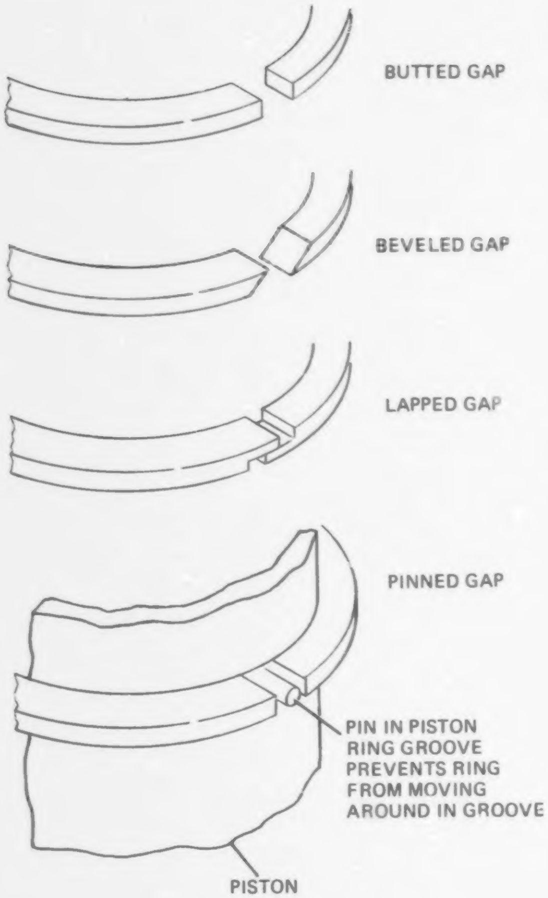

BUTTED GAP
BEVELED GAP
LAPPED GAP
PINNED GAP
PIN IN PISTON RING GROOVE PREVENTS RING FROM MOVING AROUND IN GROOVE
PISTON

Figure 3-24. Ring Gap Variations.

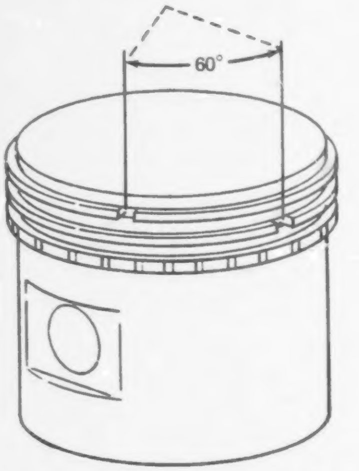


Figure 3-25. Staggered Ring Gaps.

TA233365

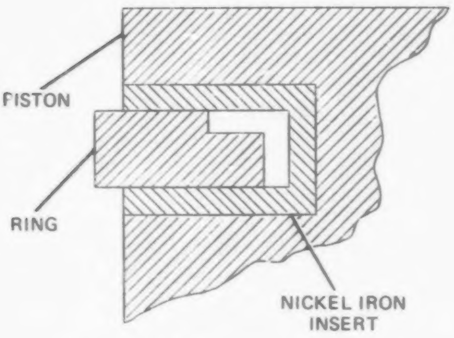

PISTON
RING
NICKEL IRON INSERT

Figure 3-26. Top Ring Groove Insert.

3-7. Piston Pins.

a. General (Fig. 3-30). The piston pin serves to connect the piston to the connecting rod. It passes through the pin bosses in the piston and the upper end of the connecting rod.

b. Construction (Fig. 3-31). A piston pin must be hard to provide the desired wearing qualities. At the same time, the piston pin must not be brittle. To satisfy the overall requirements of a piston pin, it was found that a casehardened steel pin is best. Casehardening is a process that hardens the surface of the steel to any desired depth. The pin is also made hollow to reduce the overall weight of the reciprocating mass.

c. Configurations. The following are the three different piston pin configurations.

(1) An anchored or fixed piston pin (A, fig. 3-32) is locked into the piston pin bosses by a screw. The rod pivots freely on the connecting rod, which usually is fitted with a bronze bushing.

(2) A semifloating pin (B, fig. 3-32) is locked to the connecting rod by a screw or friction. The pin pivots freely in the piston pin bosses.

(3) The full-floating piston pins (C, fig. 3-32) pivot freely in the connecting rod and the piston pin bosses. The outer ends of the piston pins are fitted with lockrings to keep the pin from sliding out and contacting the cylinder walls.

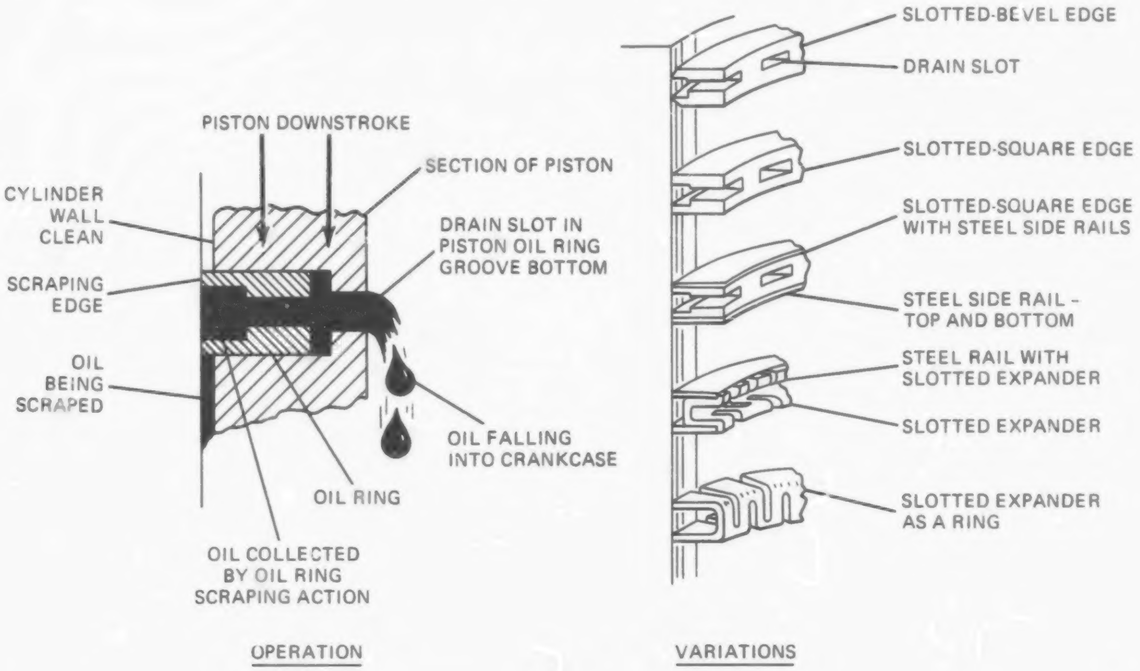

PISTON DOWNSTROKE
SECTION OF PISTON
CYLINDER WALL CLEAN
DRAIN SLOT IN PISTON OIL RING GROOVE BOTTOM
SCRAPING EDGE
OIL BEING SCRAPED
OIL FALLING INTO CRANKCASE
OIL RING
OIL COLLECTED BY OIL RING SCRAPING ACTION
OPERATION
SLOTTED-BEVEL EDGE
DRAIN SLOT
SLOTTED-SQUARE EDGE
SLOTTED-SQUARE EDGE WITH STEEL SIDE RAILS
STEEL SIDE RAIL - TOP AND BOTTOM
STEEL RAIL WITH SLOTTED EXPANDER
SLOTTED EXPANDER
SLOTTED EXPANDER AS A RING
VARIATIONS

Figure 3-27. Oil Control Rings.

TA233366

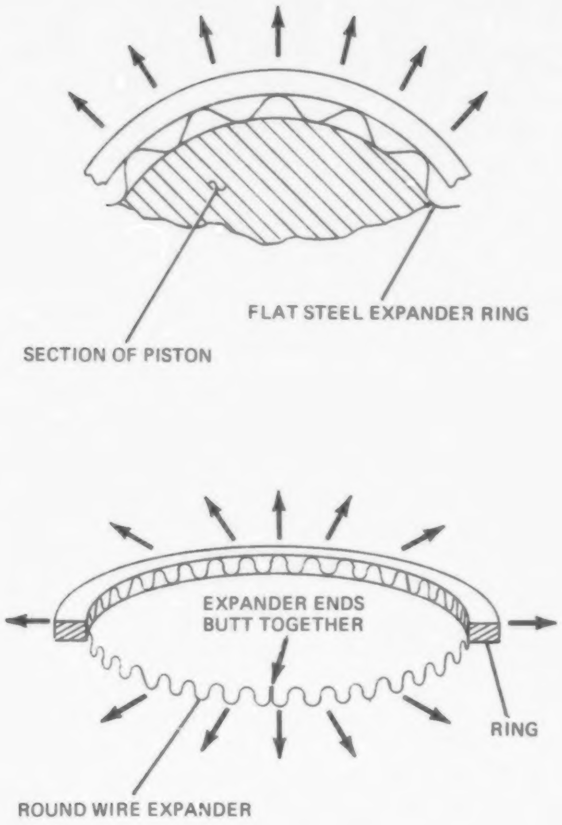

FLAT STEEL EXPANDER RING
SECTION OF PISTON
EXPANDER ENDS BUTT TOGETHER
RING
ROUND WIRE EXPANDER

Figure 3-28. Piston Ring Expanders.

3-8. Connecting Rods.

a. General (Fig. 3-33). The connecting rods connect the pistons to the crankshaft. They must be extremely strong to transmit the thrust of the pistons to the crankshaft, and to withstand the inertial forces of the directional changes of the pistons.

b. Construction (Fig. 3-33). The connecting rods are normally in the form of an I-beam. This design gives the highest overall strength and lowest weight. They usually are made of forged steel, but may be made of aluminum in small engines. The upper end attaches to the piston pin, which connects it to the piston. The lower end is attached to the crankshaft. The lower bearing hole in the connecting rod is split so that it may be clamped to the crankshaft. Because the lower end has much greater movement than the upper, the hole is much larger. This provides much greater bearing surface.

3-9. Crankshaft.

a. General (Fig. 3-34). The crankshaft is the part of the engine that transforms the reciprocating motion of the pistons to rotating motion.

b. Construction (Fig. 3-34). Crankshafts are made from forged or cast steel. The forged steel unit is the stronger of the two. It usually is reserved for commercial and military use. The cast unit is used primarily in light and regular duty gasoline engines. After the rough forging or casting is produced, it becomes a finished product by going through the following steps:

(1) All surfaces are rough machined.

(2) All holes are located and drilled.

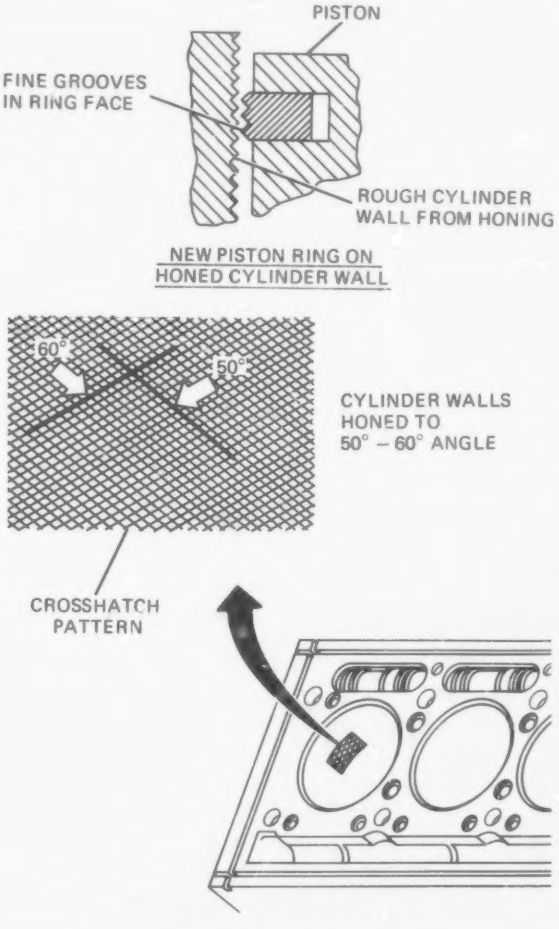

PISTON
FINE GROOVES IN RING FACE
ROUGH CYLINDER WALL FROM HONING
NEW PISTON RING ON HONED CYLINDER WALL
60°
50°
CYLINDER WALLS HONED TO 50° – 60° ANGLE
CROSSHATCH PATTERN

Figure 3-29. Piston Ring Wear-In.

TA233367

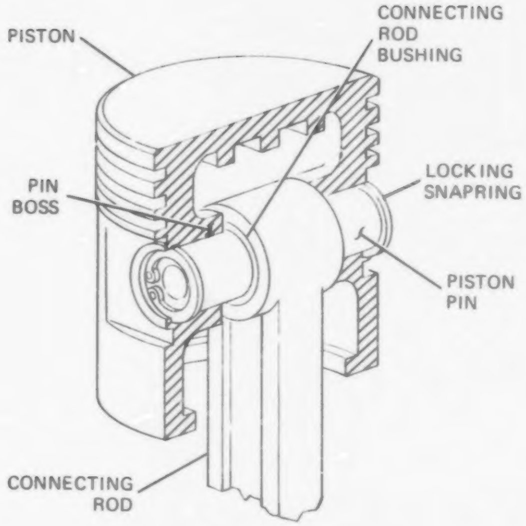


Figure 3-30. Piston Pin.

(3) The crankshaft, with the exception of the bearing journals, is plated with a light coating of copper.

(4) The bearing journals are case-hardened.

(5) The bearing journals are ground to size.

(6) Threads are cut into necessary boltholes.

c. Throw Arrangements (Fig. 3-35). The arrangement of the throws on the crankshaft determines the firing order of the engine. The position of the throws for each cylinder arrangement is paramount to the overall smoothness of operation. For the various engine configurations, typical throws are arranged as follows:

(1) In-line four-cylinder engines have throws one and four offset 180 degrees from throws two and three.

(2) V-type engines have two cylinders operating off of each throw. The two end throws are on one plane offset 180 degrees apart. The two center throws are on another common plane. They are also offset 180 degrees apart. The two planes are offset 90 degrees from each other.

(3) In-line six-cylinder engines have their throws arranged on three planes. There are two throws on each plane that are in line with each other. The three planes are arranged 120 degrees apart.

(4) V-type 12-cylinder engines have throw arrangements like the in-line six-cylinder engines. The difference is that each throw accepts two-engine cylinders.

(5) V-type six-cylinder engines have three throws at 120-degree intervals. Each throw accepts two-engine cylinders.

d. Crankshaft Vibration. A crankshaft is very prone to vibration because of its shape, extreme weight, and the tremendous forces acting on it. The following are three basic areas that are of concern when considering vibration in crankshaft design.

(1) *Vibration Due to Imbalance (Fig. 3-36).* An inherent problem with a crankshaft is

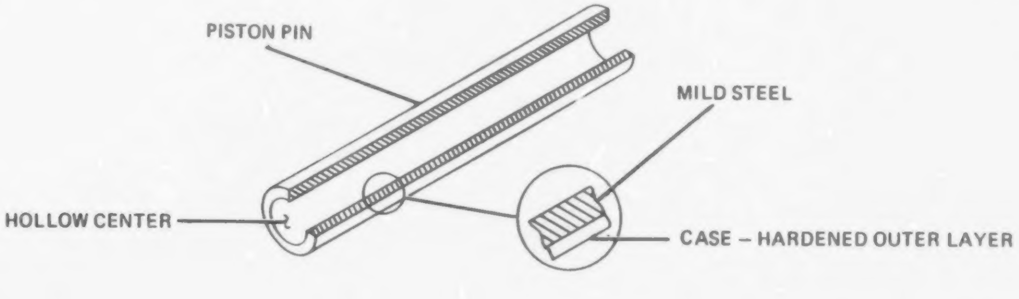


Figure 3-31. Piston Pin Construction.

TA233368

62

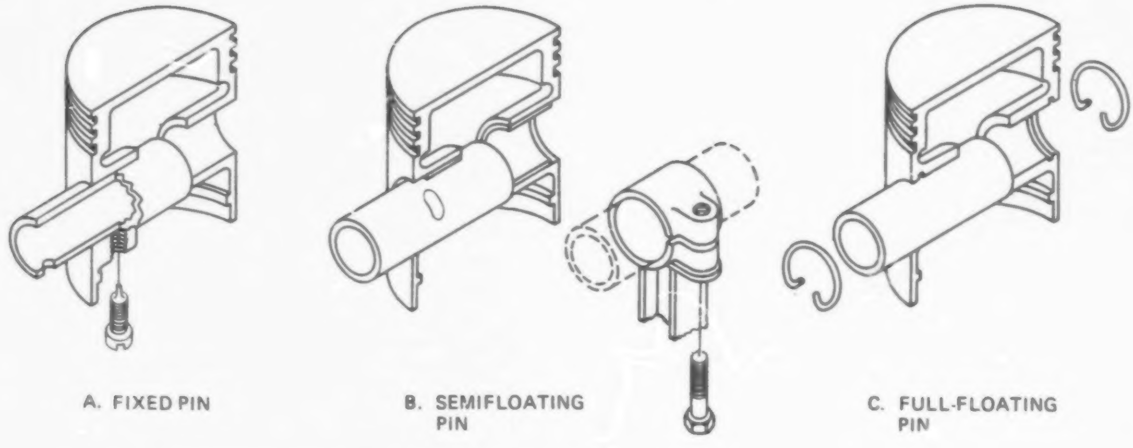


Figure 3-32. Piston Pin Configurations.

that it is made with offset throws. The weight of the throws tend to make the crankshaft rotate elliptically. This is aggravated further by the weight of the piston and the rod. To eliminate the problem, weights are positioned along the crankshaft. One weight is placed 180 degrees away from each throw. They are called counterweights and are usually part of the crankshaft, but may be separate bolt-on items on small engines.

(2) *Vibration Due to Deflection.* The crankshaft will have a tendency to bend slightly when subjected to the tremendous thrust from the piston. This deflection of the rotating member will cause a vibration. This vibration is minimized by heavy crankshaft construction and sufficient support along its length by bearings.

(3) *Torsional Vibration (Fig. 3-37).* Torsional vibration occurs when the crankshaft twists because of the power stroke thrusts. It is particularly noticeable on engines with long crankshafts, such as in-line engines. It is a major reason why in-line, eight-cylinder engines are no longer produced. The vibration is caused by the cylinders furthest from the crankshaft output. As these cylinders apply thrust to the crankshaft, it twists, and as the thrust decreases, the crankshaft unwinds. The twisting and unwinding of the crankshaft produces a vibration. The use of a

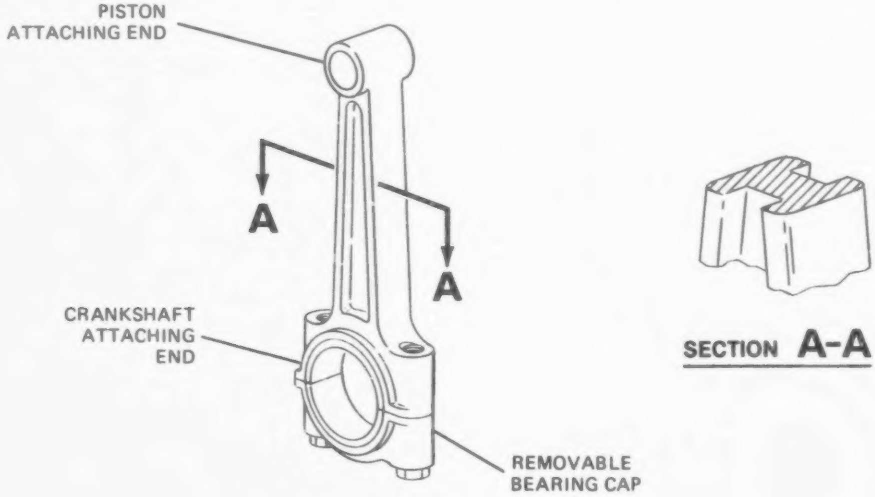


Figure 3-33. Connecting Rod Construction.

TA233369

63

BEST COPY AVAILABLE

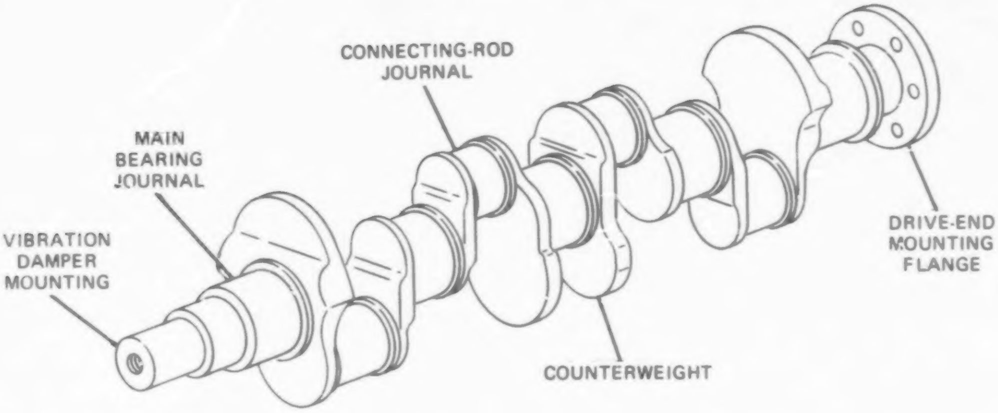


Figure 3-34. Crankshaft Construction.

vibration damper at the end of the crankshaft opposite the output end will serve to absorb torsional vibration. There are a few variations of the vibration damper, but they all accomplish their task in basically the same manner. They all employ a two-piece design. The differences in design are in how the two pieces are linked together. One type of damper links the pieces together by an adjustable friction clutch. Whenever a sudden change in crankshaft speed occurs, it causes the friction clutch to slip. This is because the outer section of the damper will tend to continue at the same speed. The slippage of the clutch serves to absorb the torsional vibration. Another type of damper links the two pieces together with rubber. As the crankshaft speeds up, the rubber compresses, storing energy. This serves to minimize the effect of crankshaft speed increase. As the crankshaft unwinds, the damper releases the energy stored in the compressed rubber to cushion the speed change in the other direction.

e. Lubrication (Fig. 3-38). The crankshaft has internal drilled passages to supply lubrication to its bearings.

3-10. Crankshaft Bearings.

a. General (Fig. 3-39). The crankshaft is supported in the crankcase and rotates in the main bearings. The connecting rods are supported on the crankshaft by the rod bearings.

b. Construction (Fig. 3-40). Crankshaft bearings are made as precision inserts. They simply slip into place in the upper and lower halves of the shells. When the halves are clamped together, they form a precision bearing that will be a perfect fit for a properly sized shaft. The bearing inserts and the mating surface that hold them must be sized perfectly. The insert merely slips into place and is held from turning by the locating tab.

c. Materials (Fig. 3-41). Most bearings begin with a steel backing to give them rigidity. The lining then is applied to the steel backing. The lining usually consists of an alloy of copper, tin, and lead. The lining also may be made of babbit. Babbit is a popular bearing material that is an alloy consisting of copper, tin, and antimony. The lining thickness usually ranges from 0.002 to 0.005 in. (0.051 to 0.127 mm). The bearing then is coated with either aluminum or tin to a thickness of approximately 0.001 in. (0.025 mm).

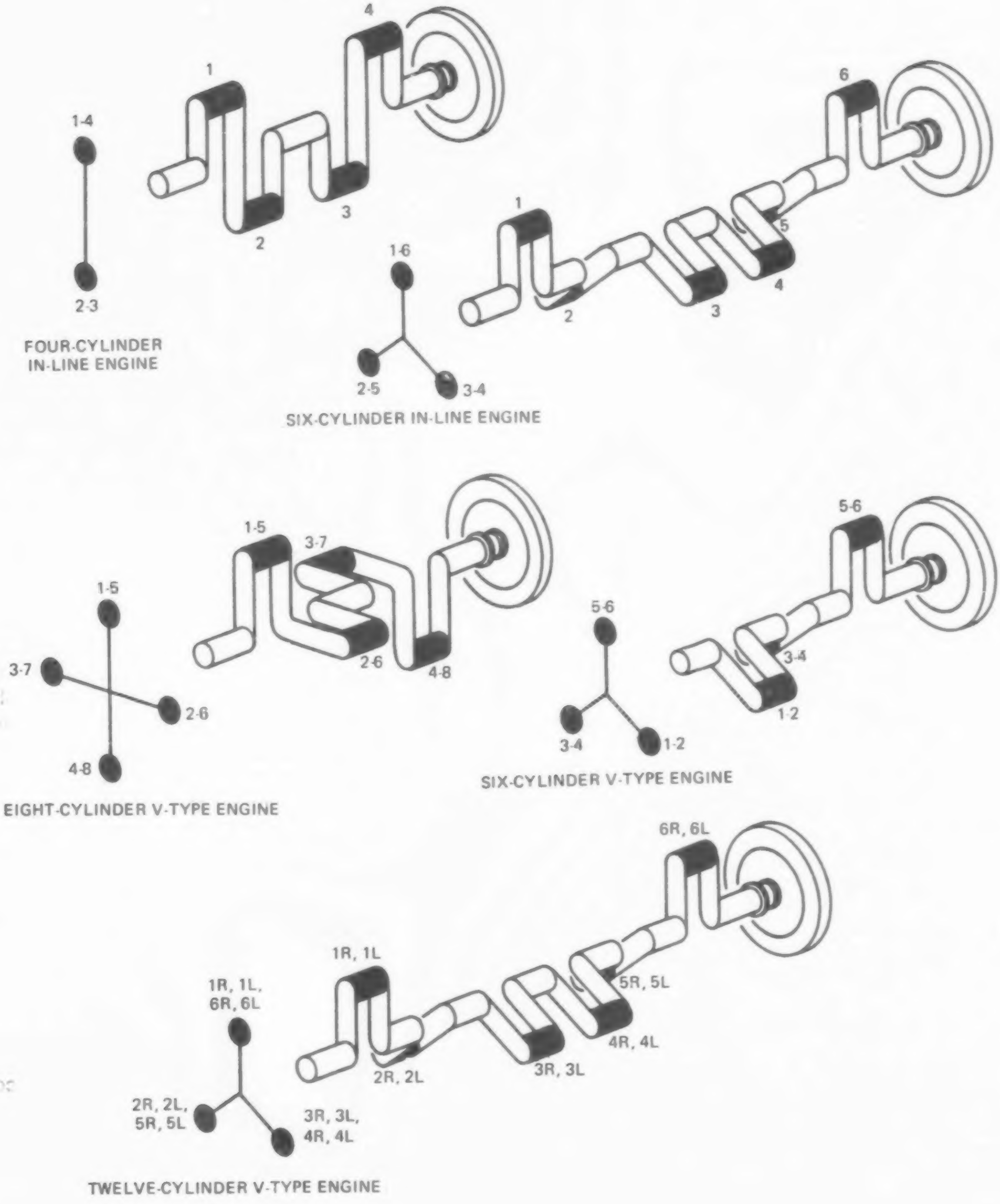
d. Bearing Requirements (Fig. 3-42). Bearings must be able to support the crankshaft rotation and deliver power-stroke thrusts under the most adverse conditions. A good bearing must have the following qualities.

(1) *Strength.* Engine bearings are constantly subjected to tremendous forces from the thrust of the power strokes. The bearings must be able to withstand these loads without spreading out or cracking.

(2) *Corrosion.* The bearing must be resistant to moisture and acids that always are present in the crankcase.

TA233370

61


4
1
1-4
3
2
2-3
6
1
5
1-6
4
2
3
2-5
3-4
1-5
3-7
1-5
3-7
2-6
4-8
2-6
4-8
5-6
5-6
3-4
1-2
3-4
1-2
6R, 6L
1R, 1L
1R, 1L,
6R, 6L
5R, 5L
4R, 4L
2R, 2L
3R, 3L
2R, 2L,
5R, 5L
3R, 3L,
4R, 4L

FOUR-CYLINDER IN-LINE ENGINE

SIX-CYLINDER IN-LINE ENGINE

EIGHT-CYLINDER V-TYPE ENGINE

SIX-CYLINDER V-TYPE ENGINE

TWELVE-CYLINDER V-TYPE ENGINE

Figure 3-35. Crankshaft Throw Arrangements.

TA233371

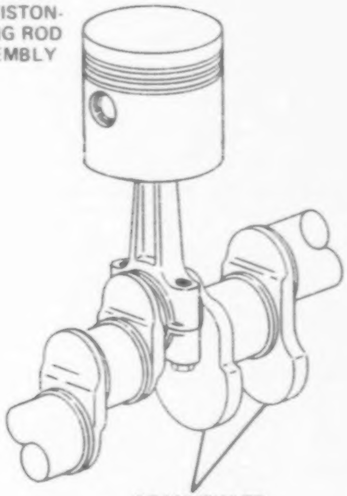

COUNTERWEIGHTS COUNTERBALANCE THE IMBALANCE CAUSED BY WEIGHT OF PISTON-CONNECTING ROD ASSEMBLY
CRANKSHAFT COUNTERWEIGHTS

Figure 3-36. Crankshaft Counterweights.

(3) *Antiscuffing.* The bearing surface should be able to absorb enough oil to keep it from scuffing during startup, or any other time when it must run momentarily without an oil supply.

(4) *Embedability.* The surface of the bearing must be soft enough to allow particles of foreign matter to embed themselves and prevent damage of the shaft journal.

(5) *Conformability.* The bearing must be able to conform or fit itself to the surface of the crankshaft journal.

(6) *Conductivity.* The bearings must be able to conduct heat to the connecting rod so that they will not overheat.

(7) *Resistance to Heat.* The bearing must be able to maintain all of these characteristics throughout its entire operating temperature range.

e. Connecting Rod Lubrication (Fig. 3-43). The connecting rod bearings fit into the lower end of the connecting rod. They are fed a constant supply of oil through a hole in the crankshaft journal. A hole in the upper bearing half feeds a passage in the connecting rod to provide oil to the piston pin.

f. Crankshaft Main Bearings (Fig. 3-44). The upper halves of the main bearings fit right into the crankcase, and the lower halves fit into the caps that hold the crankshaft in place. The main bearings have holes drilled in their upper halves through which a supply of oil is fed to them. The crankshaft has holes drilled in the journals that receive oil from the main bearings to feed the rod bearings. It is a common practice to cut a groove in the center of the main bearing inserts. This supplies a more constant supply of oil to the connecting rod bearings. One of the main bearings also serves as a thrust bearing. This controls back and forth movement of the crankshaft. This thrust bearing is characterized by side flanges.

3-11. Flywheel (Fig. 3-45).

a. General. The flywheel stores energy from the power strokes, and smoothly delivers it to the drive train of the vehicle. It mounts on the end of the crankshaft, between the engine and the transmission.

b. Manual Transmission. When the vehicle is equipped with a manual transmission, the flywheel serves to mount the clutch.

c. Automatic Transmission. When the vehicle is equipped with an automatic transmission, the flywheel serves to support the front of the torque converter. On some configurations, the flywheel is combined with the torque converter.

d. Starter Ring Gear. The outer edge of the flywheel is lined with gear teeth. They are to engage the drive gear on the starter motor.

e. Construction. The flywheel on large, low-speed engines usually is made of cast iron. This is desirable due to the heavy weight of the cast iron, which helps the engine maintain a steady speed. Small, high-speed engines usually use a forged steel or forged aluminum flywheel for the following reasons.

(1) The cast iron is too heavy, giving it too much inertia to allow the speed variations necessary on small engines.

(2) Cast iron, because of its weight, will pull itself apart at high speeds due to centrifugal force.

TA233372

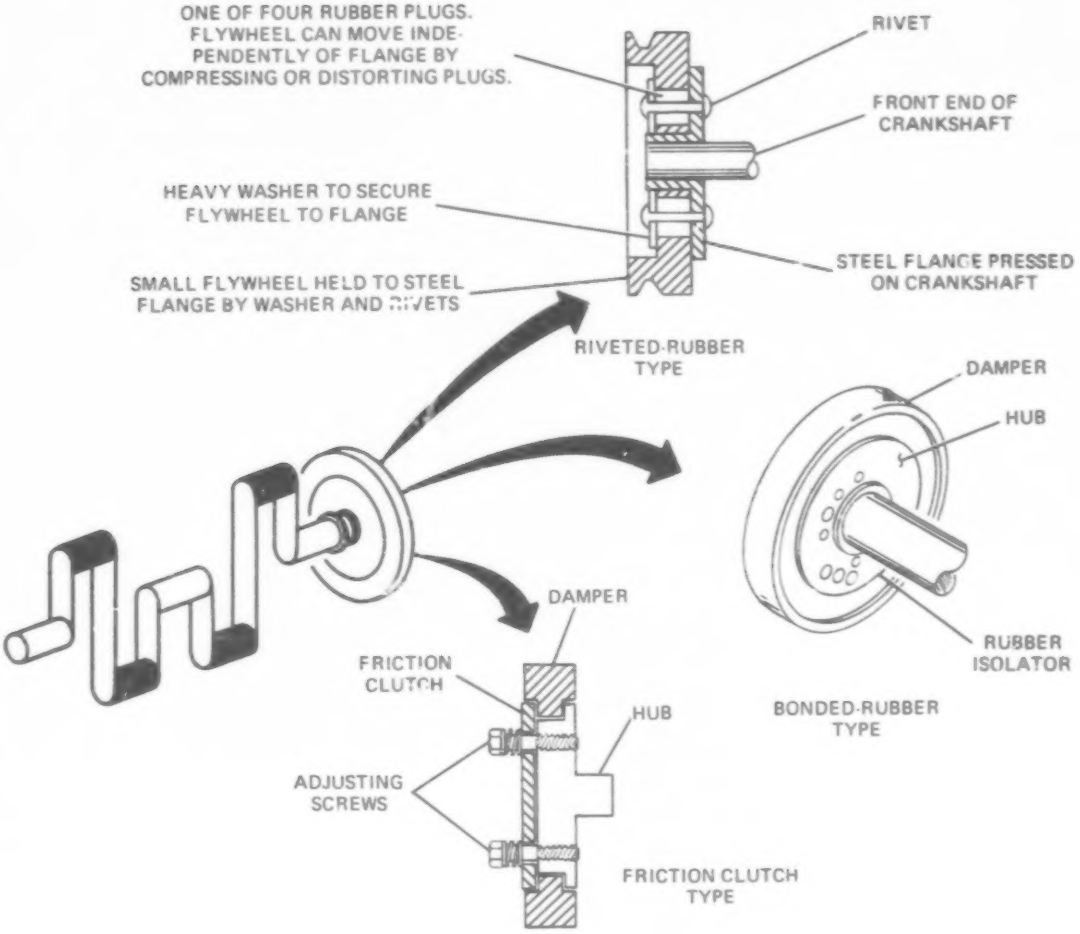

ONE OF FOUR RUBBER PLUGS. FLYWHEEL CAN MOVE INDEPENDENTLY OF FLANGE BY COMPRESSING OR DISTORTING PLUGS.
RIVET
FRONT END OF CRANKSHAFT
HEAVY WASHER TO SECURE FLYWHEEL TO FLANGE
STEEL FLANGE PRESSED ON CRANKSHAFT
SMALL FLYWHEEL HELD TO STEEL FLANGE BY WASHER AND RIVETS
RIVETED-RUBBER TYPE
DAMPER
HUB
RUBBER ISOLATOR
BONDED-RUBBER TYPE
DAMPER
FRICTION CLUTCH
HUB
ADJUSTING SCREWS
FRICTION CLUTCH TYPE

Figure 3-37. Vibration Damper.

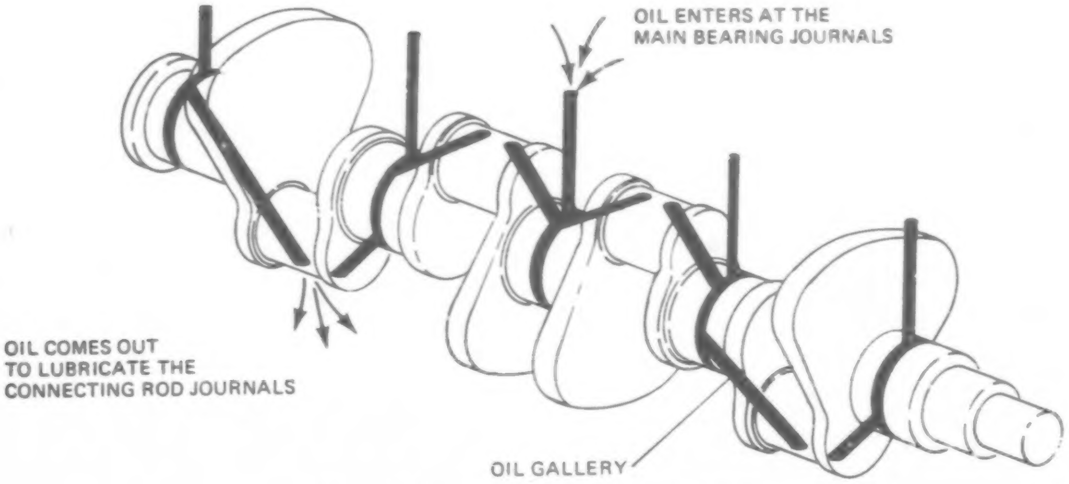

OIL ENTERS AT THE MAIN BEARING JOURNALS
OIL COMES OUT TO LUBRICATE THE CONNECTING ROD JOURNALS
OIL GALLERY

Figure 3-38. Crankshaft Lubrication Passages.

TA233373

67

BEST COPY AVAILABLE

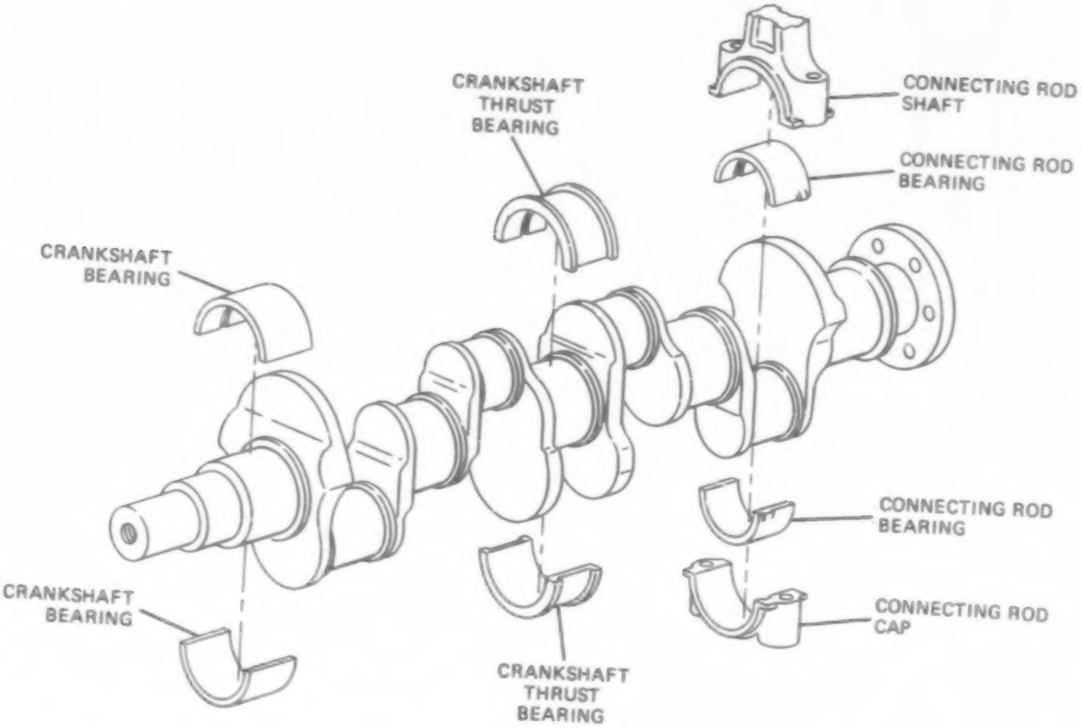

CRANKSHAFT
THRUST
BEARING
CONNECTING ROD
SHAFT
CONNECTING ROD
BEARING
CRANKSHAFT
BEARING
CONNECTING ROD
BEARING
CRANKSHAFT
BEARING
CONNECTING ROD
CAP
CRANKSHAFT
THRUST
BEARING

Figure 3-39. Crankshaft Bearings.

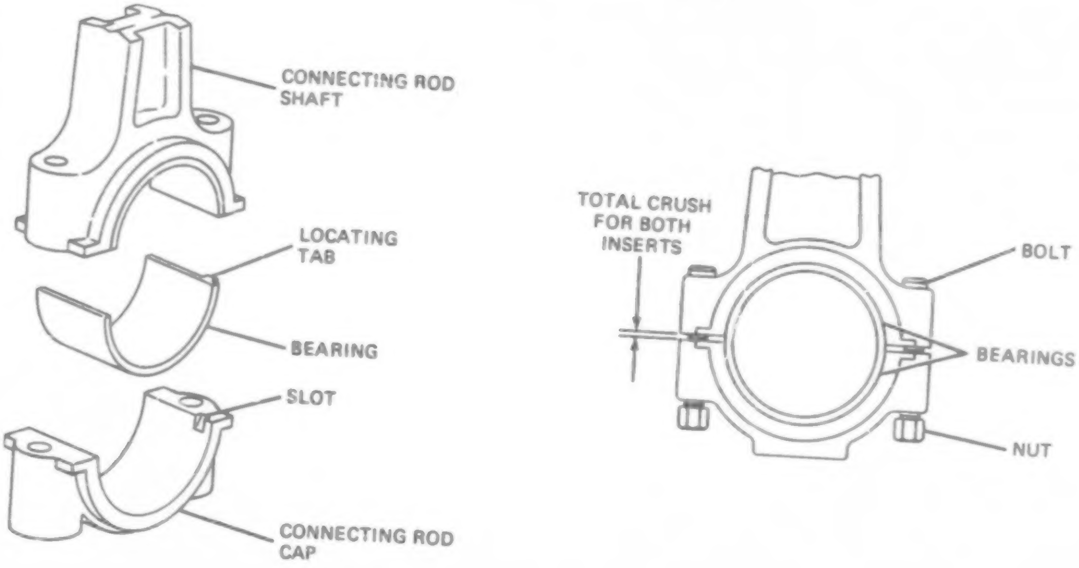

CONNECTING ROD
SHAFT
LOCATING
TAB
BEARING
SLOT
CONNECTING ROD
CAP
TOTAL CRUSH
FOR BOTH
INSERTS
BOLT
BEARINGS
NUT

Figure 3-40. Typical Insert Bearing Installation.

TA233374

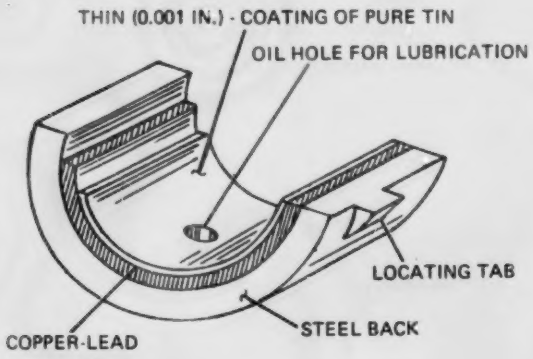

THIN (0.001 IN.) - COATING OF PURE TIN
OIL HOLE FOR LUBRICATION
LOCATING TAB
STEEL BACK
COPPER-LEAD

Figure 3-41. Bearing Materials.

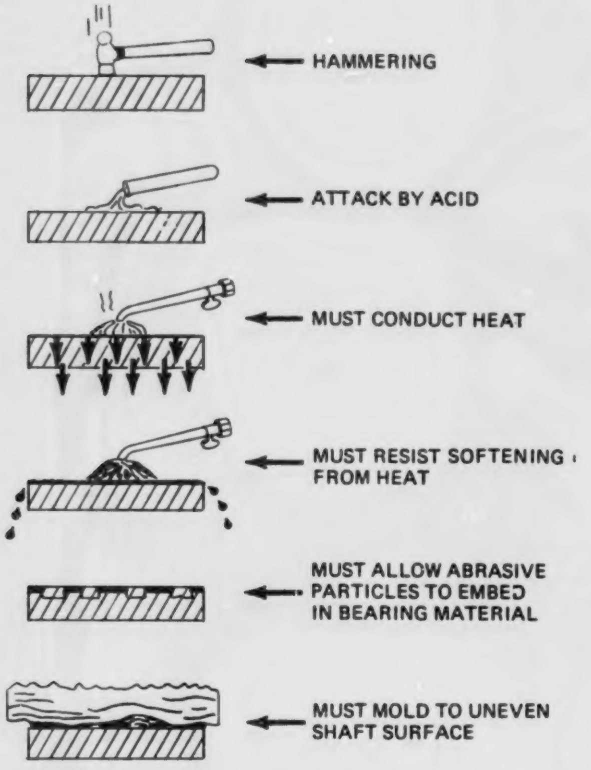

HAMMERING
ATTACK BY ACID
MUST CONDUCT HEAT
MUST RESIST SOFTENING FROM HEAT
MUST ALLOW ABRASIVE PARTICLES TO EMBED IN BEARING MATERIAL
MUST MOLD TO UNEVEN SHAFT SURFACE

Figure 3-42. Bearing Requirements.

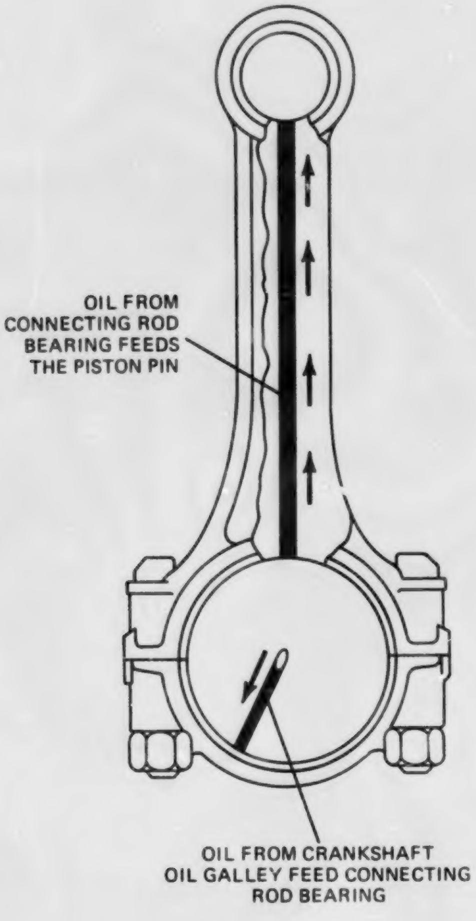

OIL FROM CONNECTING ROD BEARING FEEDS THE PISTON PIN
OIL FROM CRANKSHAFT OIL GALLEY FEED CONNECTING ROD BEARING

Figure 3-43. Connecting Rod Lubrication.

TA233375

69

BEST COPY AVAILABLE

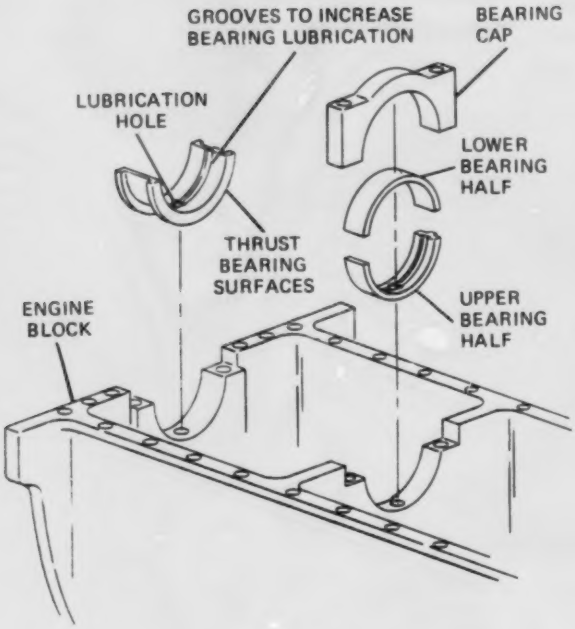

GROOVES TO INCREASE BEARING LUBRICATION
BEARING CAP
LUBRICATION HOLE
LOWER BEARING HALF
THRUST BEARING SURFACES
UPPER BEARING HALF
ENGINE BLOCK

Figure 3-44. Crankshaft Main Bearings.

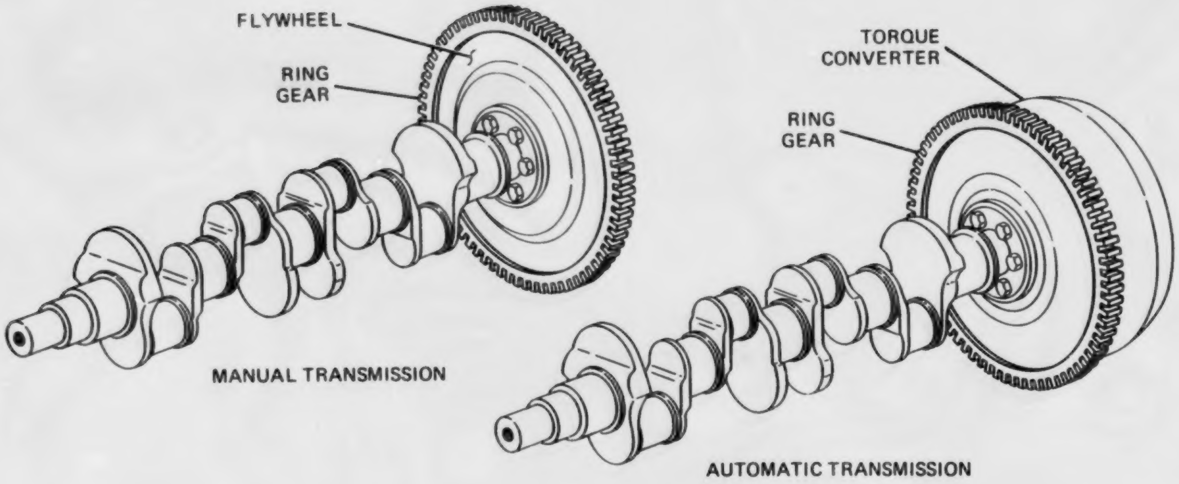

FLYWHEEL
RING GEAR
TORQUE CONVERTER
RING GEAR
MANUAL TRANSMISSION
AUTOMATIC TRANSMISSION

Figure 3-45. Flywheel.

TA233376

70

Section III. VALVES AND OPERATING MECHANISMS

3-12. Valves and Seats.

a. General (Fig. 3-46). Each cylinder in a four-stroke cycle engine must have one intake and one exhaust valve. The valves that are commonly used are of the poppet design. The word poppet is derived from the popping action of the valve. Poppet-type valves are made in the following three basic shapes: the mushroom, semitulip, and tulip. The valve shape that is used in a given engine is dependent upon the requirements and combustion chamber shape.

b. Construction. Construction and design considerations are very different between intake and exhaust valves. The difference is based on their temperature operating ranges. Intake valves are kept cool by the incoming intake mixture. Exhaust valves are subject to intense heat from the burnt gases that pass by it. The temperature of the exhaust valve can be in excess of 1300°F (704.4°C). Intake valves are made of a nickel chromium alloy. Exhaust valves are made of a silichrome alloy. In certain heavy-duty water-cooled and most air-cooled engines, the exhaust valves are hollowed out and filled partially with metallic sodium (B, fig. 3-47). The sodium, which liquifies at operating temperatures, splashes between the valve head, where it picks up heat, and the valve stem, where the heat is transferred to the valve guide. Some exhaust valves use a special hard facing process (A, fig. 3-47) that keeps the face of the valve from taking on the shape of the valve seat at high temperatures.

c. Valve Seats (Fig. 3-48). Valve seats are very important, as they must match the face of the valve head to form a perfect seal. The seats are made so that they are concentric with the valve guides; that is, the surface of the seat is an equal distance from the center of the guide all around. There are two common angles that are used when machining the valve seat; they are 30 and 45 degrees. The face of the valve is usually ground with a one-half to a 1-degree difference to help the parts seat quickly. In some cases, a small portion of the valve seat has an additional 15-degree angle ground into it to narrow the contact area of the valve face and seat. By reducing the contact area, the pressure between the mating parts is increased, thereby forming a better seal. The valve seats can be either part of the cylinder head or separate inserts. Valve seat inserts generally are held into the head by an interference fit.

The head is heated in an oven to a uniform high temperature and the seat insert is shrunk by cooling it in dry ice. While the two parts are at opposite temperature extremes, the seat insert is pressed into place.

d. Valve Guides (Fig. 3-49). The valve guides are the parts that support the valves in the head. They are machined to a fit of a few thousandths of an inch clearance with the valve stem. This close clearance is important for the following reasons:

(1) It keeps the lubricating oil from getting

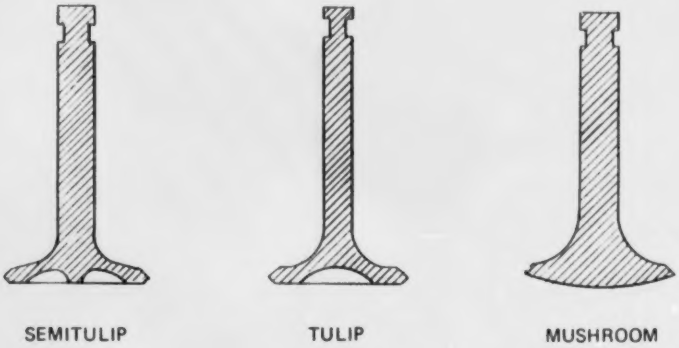
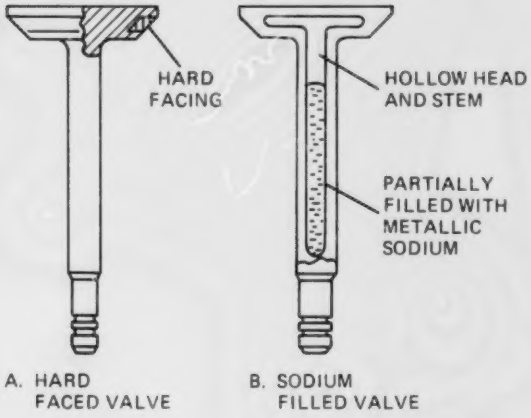


Figure 3-46. Valve Configurations.

TA233377

71

BEST COPY AVAILABLE


HARD
FACING
HOLLOW HEAD
AND STEM
PARTIALLY
FILLED WITH
METALLIC
SODIUM

A. HARD FACED VALVE B. SODIUM FILLED VALVE

Figure 3-47. Exhaust Valve Configurations.

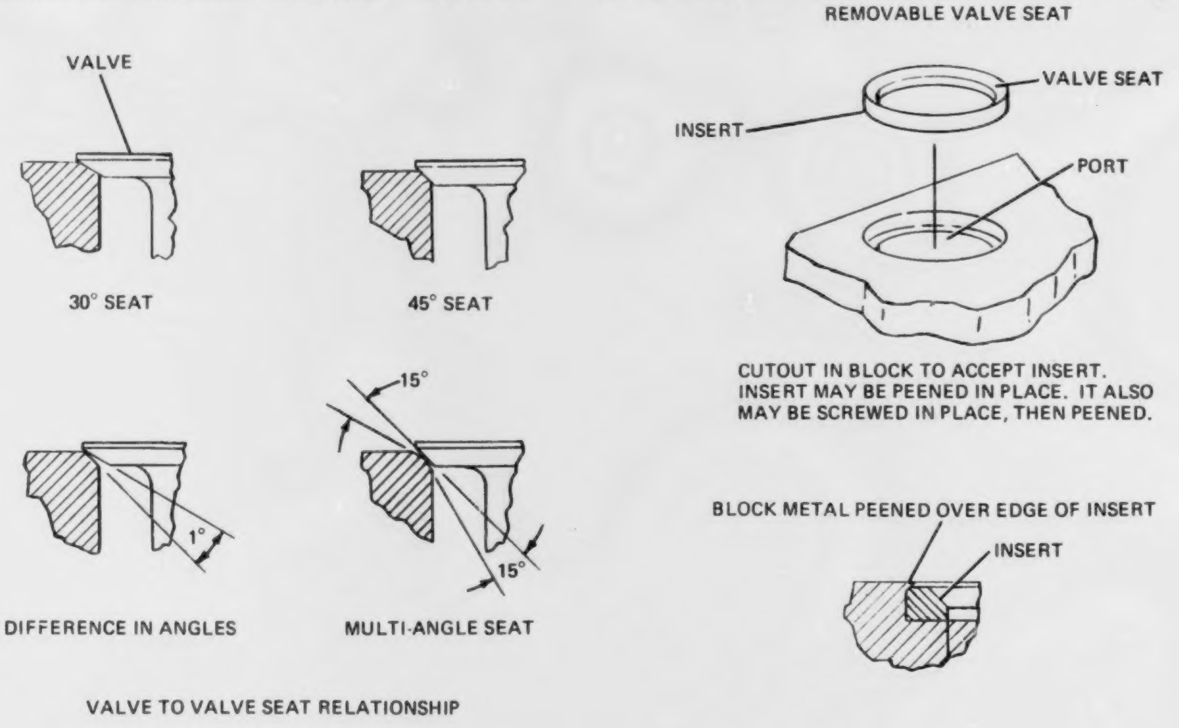
sucked into the combustion chamber past the intake valve stem during the intake stroke.

(2) It keeps exhaust gases from getting into the crankcase area past the exhaust valve stems during the exhaust stroke.

(3) It keeps the valve face in perfect alinement with the valve seat. Valve guides may be cast integrally with the head, or they may be removable. Removable valve guides usually are press fit into the head.

e. Valve Springs, Retainers, and Seals (Fig. 3-50). The valve assembly is completed by the spring, retainer, and seal. Before the spring and the retainer fit into place, a seal is placed over the valve stem. The seal acts like an umbrella to keep the valve operating mechanism oil from running down the valve stem and into the combustion chamber. The spring, which keeps the valve in a normally closed position, is held in place by the retainer. The retainer locks onto the valve stem with two wedged-shaped parts that are called valve keepers.

f. Valve Rotators. It is common in heavy-duty applications to use mechanisms that make the exhaust valves rotate. The purpose is to keep carbon from building up between the valve face and seat, which could hold the valve partially open, causing it to burn. The release-type rotator (A, fig. 3-51) releases the spring tension from the valve while open. The valve then will rotate from engine vibration. The positive rotator (B, fig. 3-51) is a two-piece valve retainer with a


VALVE
30° SEAT
45° SEAT
15°
1°
15°
DIFFERENCE IN ANGLES
MULTI-ANGLE SEAT
VALVE SEAT
INSERT
PORT
CUTOUT IN BLOCK TO ACCEPT INSERT.
INSERT MAY BE PEENED IN PLACE. IT ALSO
MAY BE SCREWED IN PLACE, THEN PEENED.
BLOCK METAL PEENED OVER EDGE OF INSERT
INSERT

VALVE TO VALVE SEAT RELATIONSHIP

REMOVABLE VALVE SEAT

Figure 3-48. Valve Seats.

TA233378

72

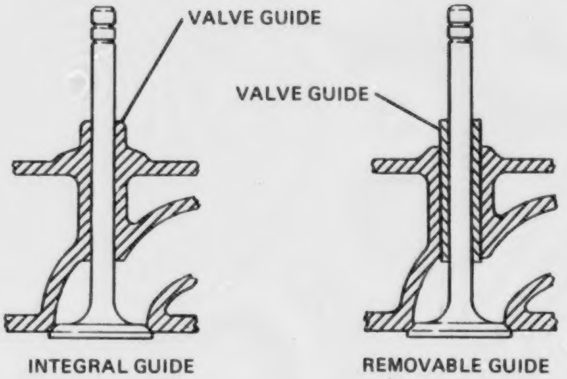


Figure 3-49. Valve Guides.

flexible washer between the two pieces. A series of balls between the retainer pieces roll on machined ramps as pressure is applied and released from the opening and the closing of the valve. The movement of the balls up and down the ramps translates into rotation of the valve.

3-13. Camshafts and Tappets.

a. General. The camshaft provides for the opening and closing of the engine valves. The tappets or the lifters are the connecting link between the camshaft and the valve mechanism.

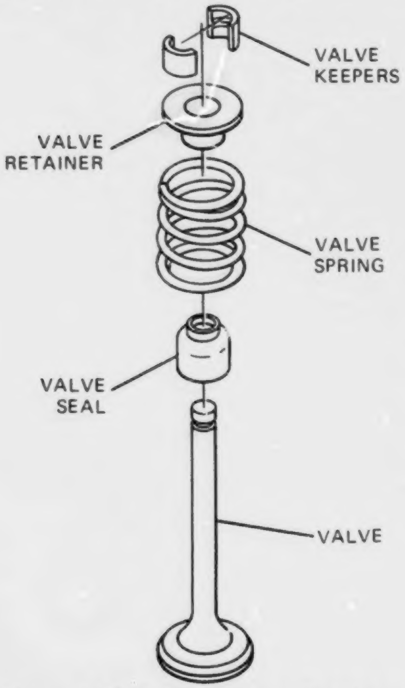


Figure 3-50. Valve Springs, Retainers, and Seals.

b. Camshaft Construction. Camshafts usually are made from cast or forged steel. The surfaces of the lobes are hardened for long life.

c. Camshaft Support (Fig. 3-52). The camshaft is supported, and rotates, in a series of bearings along its length. The bearings usually are pressed into their mountings and made of the same basic construction as crankshaft bearings. In some cases, when the engine is constructed of aluminum, the camshaft is supported directly in its mountings and no bearings are used. The thrust, or the back and forth movement, usually is taken up by the thrust plate, which bolts to the front of the engine block. Any forward thrust loads are then taken up by the front camshaft bearing journal. The drive gear or sprocket then is bolted to the front of the camshaft. Its rear surface rides against the thrust plate to take up any rearward thrust.

d. Driving the Camshaft. The following are the three basic configurations for driving the camshaft.

(1) *Gear Drive (A, Fig. 3-53).* A gear on the crankshaft meshes directly with another gear on the camshaft. The gear on the crankshaft usually is made of steel, while the gear on the camshaft may be steel for heavy-duty applications, or it may be made of aluminum or pressed fiber when quiet operation is a major consideration. The gears are helical in design (para 19-4). Helical gears are used because they are stronger, and they also tend to push the camshaft rearward during operation to help control thrust.

(2) *Chain Drive (B, Fig. 3-53).* Sprockets on the camshaft and the crankshaft are linked by a continuous chain. The sprocket on the crankshaft usually is made of steel, while the sprocket on the camshaft may be steel for heavy-duty applications. When quiet operation is a major consideration, an aluminum sprocket with a nylon covering on the teeth is used. There are two common types of timing chains. One is a silent link-type chain that is used in standard and light-duty applications. The other is the roller-link chain, which is used in heavy-duty applications. The

TA233379

73

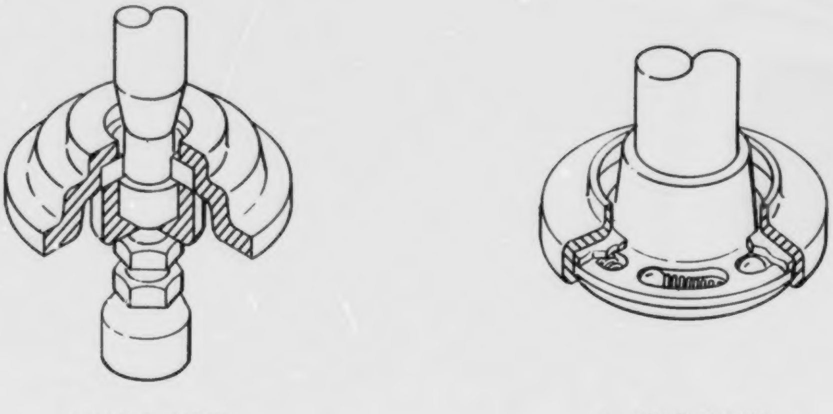


Figure 3-51. Valve Rotators.

roller link chain may have a single or a double row of links.

(3) *Belt Drive (C, Fig. 3-53).* Sprockets on the crankshaft and the camshaft are linked by a continuous neoprene belt. The belt has square-shaped internal teeth that mesh with teeth on the sprockets. The timing belt is reinforced with nylon or fiberglass to give it strength and prevent stretching. This drive configuration is limited to overhead camshaft engines.

e. Timing Belt and Chain Tensioners (Fig. 3-53). Most engines with chain-driven and all engines with belt-driven camshafts employ a tensioner. The tensioner pushes against the belt or chain to keep it tight. This serves to keep it from slipping on the sprockets, provide more precise valve timing, and compensate for component stretch and wear. Engines with belt-drive configurations usually use a spring-loaded idler wheel. Chain-driven configurations usually use a fiber rubbing block that is either spring loaded or hydraulic. The hydraulic tensioner is a device that works by the same principle as a hydraulic lifter (para 3-13h(2)). The hydraulic tensioner is much more desirable for use with a rubbing block because it takes up the slack in the chain without exerting excessive pressure, resulting in longer component life.

f. Timing Marks (Fig. 3-53) The camshaft and the crankshaft always must remain in the same relative position to each other. Because the

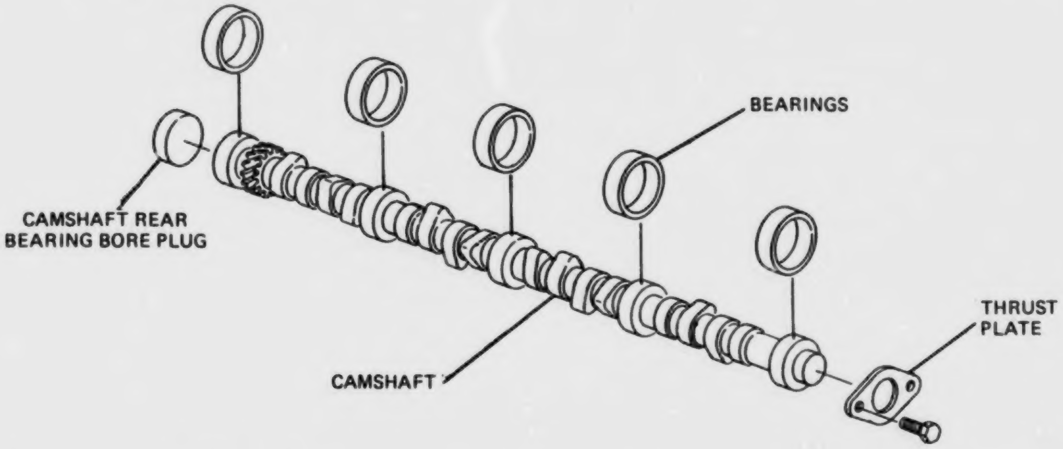
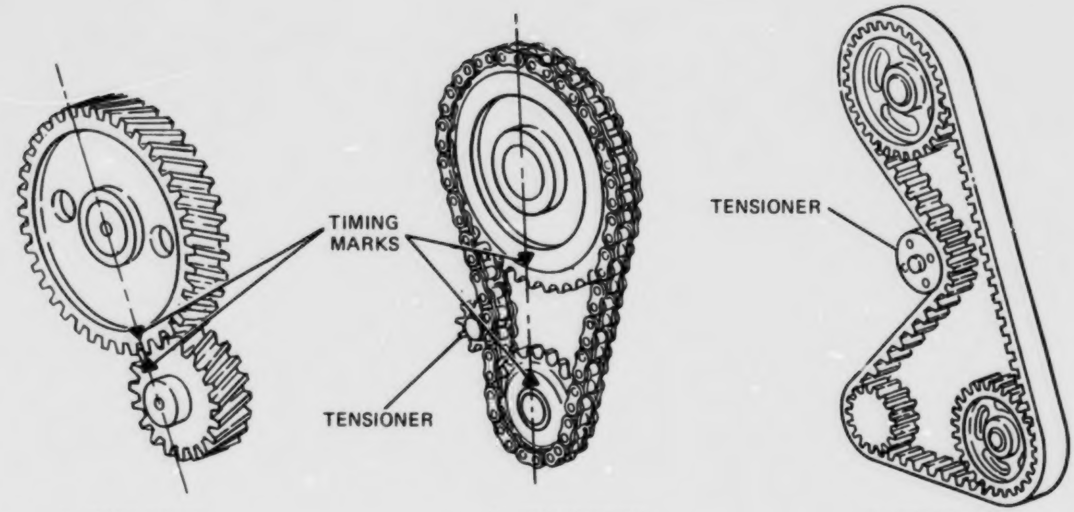


Figure 3-52. Camshaft Support.

TA233380



A. GEAR DRIVE

B. CHAIN DRIVE

C. BELT DRIVE

Figure 3-53. Driving the Camshaft.

crankshaft must rotate twice as fast as the camshaft, the drive member on the crankshaft must be exactly one-half as large as the driven member on the camshaft. In order for the camshaft and crankshaft to work together, they must be in the proper initial relation to each other. This initial position between the two shafts is designated by marks that are called timing marks. To obtain the correct initial relationship of the components, the corresponding marks are alined at the time of assembly.

g. Auxiliary Camshaft Functions (Fig. 3-54). The camshaft, after being driven by the crankshaft, in turn drives other engine components. On gasoline engines, the oil pump and the distributor usually are driven from a common gear that is machined into the camshaft. The fuel pump is also driven by the camshaft. This usually is accomplished by machining an extra lobe on the camshaft to operate the pump. On diesel engines, the camshaft often is utilized to operate the fuel injection system.

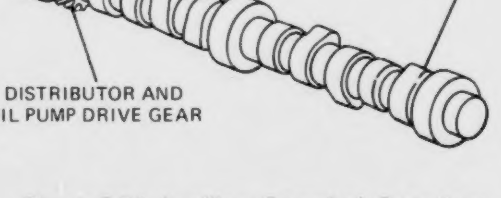


Figure 3-54. Auxiliary Camshaft Functions.

h. Tappets. Tappets (or lifters) are used to link the camshaft to the valve mechanism. The bottom surface is hardened and machined to be compatible with the surface of the camshaft lobe. The following are the two basic lifter classifications:

(1) *Mechanical Tappets (Fig. 3-55).* Mechanical (or solid) lifters are simply barrel-shaped pieces of metal. When used in flathead engines, they have an adjusting screw mechanism to set the clearance between the tappets and the valve stems. Mechanical tappets may also come with a wider bottom surface. These are called mushroom tappets. Another variation is the roller tappet, which has a roller contacting the camshaft. They are used mostly in heavy-duty applications to reduce component wear.

(2) *Hydraulic Tappets (Fig. 3-56).* The hydraulic tappet is very popular in overhead valve engines. It uses oil under pressure to automatically maintain zero clearance in the valve mechanism. The lifter body, which contacts the camshaft lobe, is hollow. Inside the lifter body, there is a plunger that operates the valve mechanism. Injecting oil into the cavity under the

TA233381

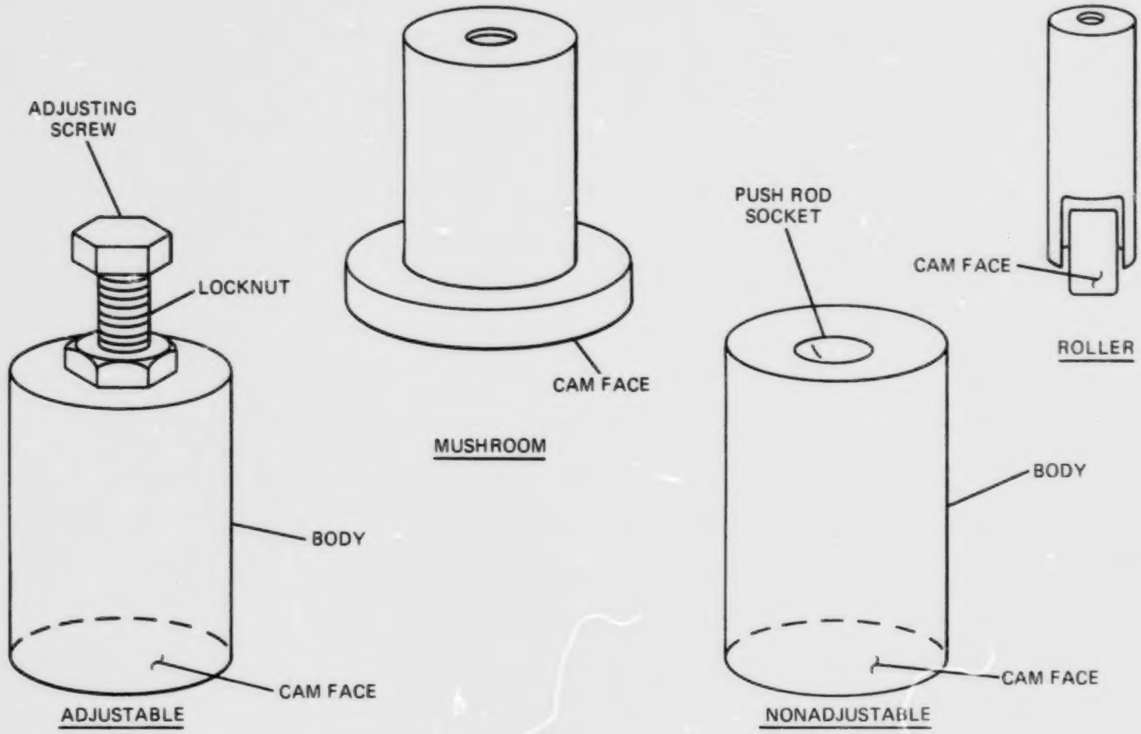


Figure 3-55. Mechanical Tappets.

plunger will regulate its height, thereby adjusting valve mechanism clearance. The hydraulic tappet operates as follows: oil, supplied by the engine lubrication system, reaches the lifter body and enters it through passage (1). The oil then passes through passage (2), to fill the plunger. The oil then passes through passage (3), where it pushes the check valve off of its seat to enter the cavity under the plunger. As the oil fills the cavity, it pushes the plunger up to where it contacts the valve mechanism. When the camshaft pushes the lifter body up, the oil is trapped in the cavity and cannot escape because the check ball seals the opening. This trapped oil then becomes a solid link between the lifter body and the plunger. The constant pressurized supply of oil will maintain zero clearance in the valve mechanism.

i. Camshaft-to-Tappet Relationship (Fig. 3-57). The face of the tappet and the lobe of the camshaft are designed so that the tappet will be made to rotate during operation. The cam lobe is machined with a slight taper that mates with a crowned lifter face. The camshaft lobe does not meet the tappet in the center of its face. Using this type of design causes the tappet face to roll and rotate on the cam lobe rather than slide. This greatly increases component life.

3-14. Valve Operating Mechanism.

a. General. The valves in overhead valve and overhead camshaft engines use additional components to link the camshaft to the valves. Overhead valve engines use push rods and rocker arms. Overhead camshaft engines use various configurations of rocker arms.

b. Push Rods (Fig. 3-58). Push rods usually are constructed of hollow steel. Most air-cooled engines use the push rods to supply lubricant to the upper valve mechanism.

c. Rocker Arms (Fig. 3-59). Rocker arms are manufactured of steel, aluminum, or cast iron. The most common for current use are the stamped steel variety. They are lightweight, strong, and cheap to manufacture. They usually pivot on a stud and ball, though some engines use a shaft arrangement. Cast iron rockers are used

76

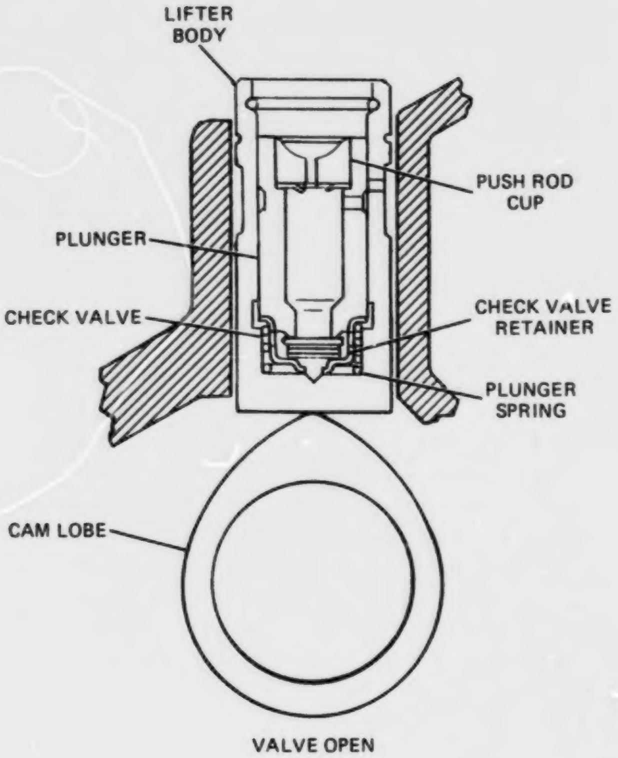

LIFTER BODY
PUSH ROD CUP
PLUNGER
CHECK VALVE
CHECK VALVE RETAINER
PLUNGER SPRING
CAM LOBE
VALVE OPEN
2
1
3
VALVE CLOSED

Figure 3-56. Hydraulic Tappets.

in larger, low-speed engines. They almost always pivot on a common shaft. Aluminum rocker arms generally are used on small high-speed applications. On special applications, such as engines used in competition, aluminum rocker arms will be pivoted in needle bearings.

d. Adjusting Clearance (Fig. 3-60). The provision for adjusting valve clearance on solid-tappet, valve-in-head engines is usually in the form of a screw on the rocker arm. On overhead valve (or push rod engines), there is usually a screw-type adjustment where the push rod actuates it. The adjusting screw can either be of the self-locking type, or have a jamnut to lock it. A few engines are equipped with adjustments on the push rods. Most overhead camshaft engines use an adjustable mounting pivot. By turning the

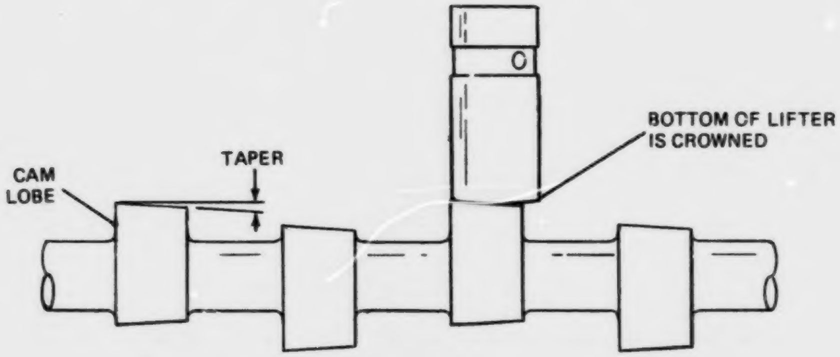

TAPER
CAM LOBE
BOTTOM OF LIFTER IS CROWNED

Figure 3-57. Tappet-to-Cam Lobe Relationship.

TA233383

77

BEST COPY AVAILABLE

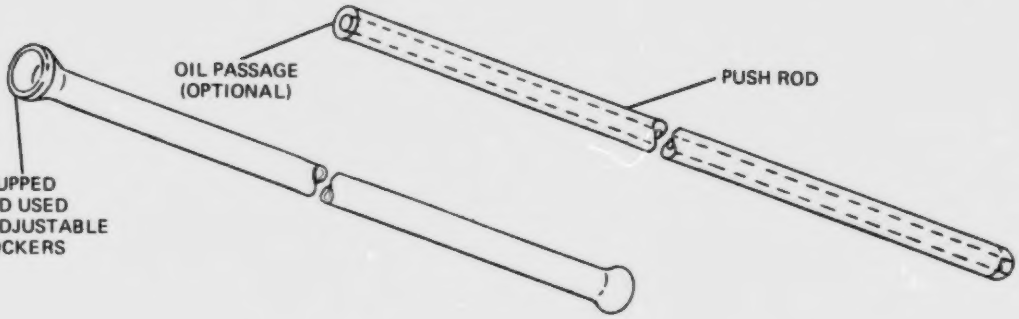

OIL PASSAGE (OPTIONAL)
PUSH ROD
CUPPED END USED WITH ADJUSTABLE ROCKERS

Figure 3-58. Push Rod.

adjusting screw, the height of the rocker arm changes. On some overhead camshaft engines, the camshaft is positioned directly over the top of the valve stems. On these engines, the valve clearance is adjusted by putting selective shims between the cam lobe and the lifter. Various thicknesses of the shims are used to obtain the desired clearances.

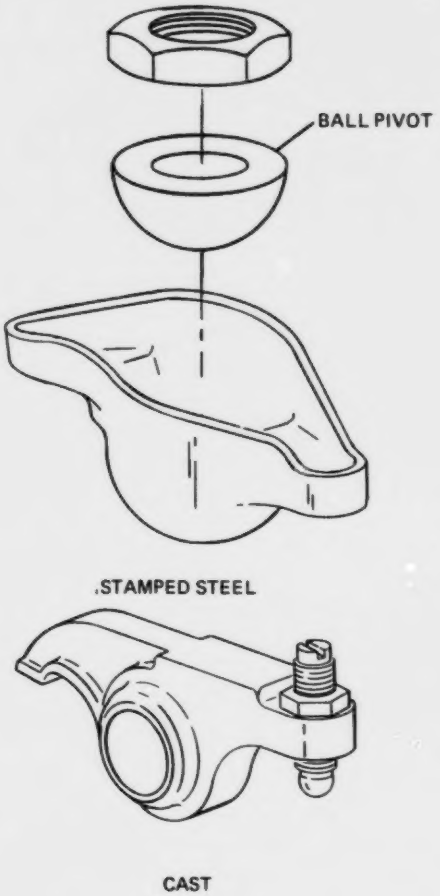

BALL PIVOT
STAMPED STEEL
CAST

Figure 3-59. Rocker Arms.

TA233384

78

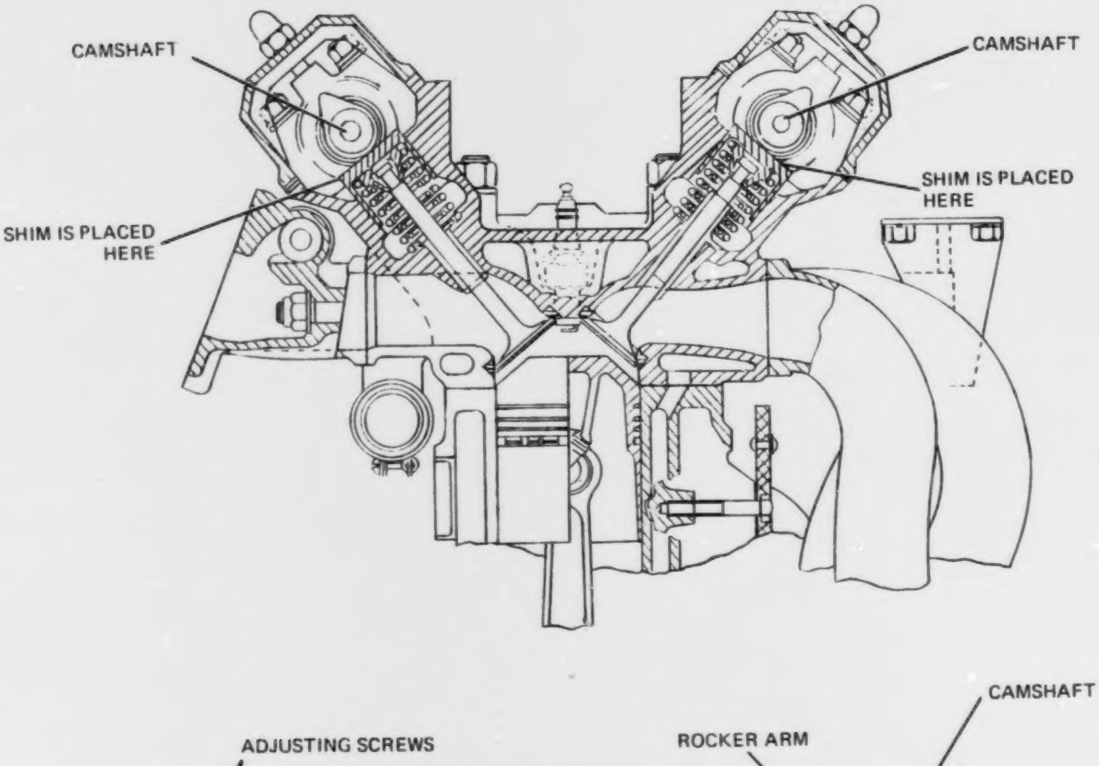

CAMSHAFT
CAMSHAFT
SHIM IS PLACED HERE
SHIM IS PLACED HERE
CAMSHAFT
ADJUSTING SCREWS
ROCKER ARM
ROCKER ARM SHAFTS
HYDRAULIC LASH ADJUSTER

Figure 3-60. Examples of Adjusting Valve Clearance.

TA233385

79

BEST COPY AVAILABLE

CHAPTER 4

GASOLINE FUEL SYSTEMS

Section I. COMPONENTS AND THEIR PURPOSES

4-1. Fuel Tanks.

a. *Purpose.* The fuel tank is for storage of gasoline in liquid form.

b. *Location (Fig. 4-1).* The location of the fuel tank is dependent on utilizing an area that is protected from flying debris, shielded from collision damage, and one that is not subject to bottoming. A fuel tank can be located just about anywhere in the vehicle that meets these requirements.

c. *Construction.* Fuel tanks take many forms in military vehicles such as those described below.

(1) The removable fuel tank (fig. 4-2) is most commonly used in wheeled vehicles. The most common material for fuel tanks is thin sheet metal that is coated with a lead-tin alloy to prevent corrosion. Because corrosion is of major concern, fiberglass and a variety of molded plastics are also popular for the manufacture of fuel tanks. The walls of the tank are manufactured with ridges to give them strength. Internal baffles are installed in the tank to prevent the fuel from sloshing and to increase overall strength. Some tanks are made with a double wall with a layer of latex rubber in between. The purpose of the wall is to make the tank self-sealing.

(2) The fuel cell (fig. 4-3) is a compartment that is integral with the body or the hull of the vehicle. Fuel cells can be located anywhere that there is an empty space. They are used in vehicles that require large fuel storage capacity. A fuel cell can take advantage of hollow areas of the vehicle where use of a removable fuel tank would be impractical. Fuel cells are suited particularly for combat situations because they may be located in areas that provide a maximum of shielding.

(3) The bladder-type fuel cell (fig. 4-4) is much the same as a fuel cell, except for the addition of a flexible liner. The liner serves to seal the cell much like an inner tube seals a tire.

d. *Filler Pipe (Fig. 4-2).* A pipe is provided for filling the tank or cell that is designed to prevent

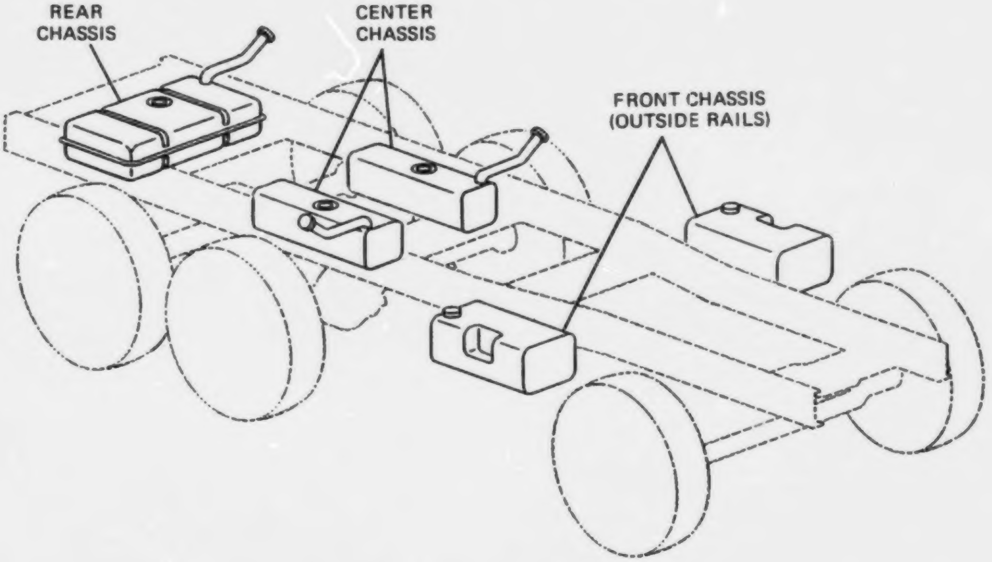


Figure 4-1. Common Fuel Tank Locations.

TA233386

80

BEST COPY AVAILABLE

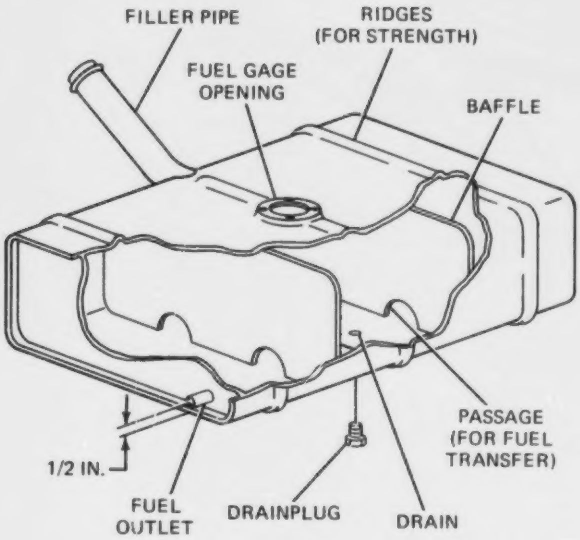


Figure 4-2. Typical Removable Fuel Tank Construction.

fuel from being spilled into the passenger, engine, or cargo compartment. The filler pipes used on military vehicles are designed to allow their tanks or cells to be filled at a rate of at least 50 gallons (189.25 liters) per minute.

e. Fuel Outlet (Fig. 4-2). The outlet pipe is located approximately 1/2 in. (1.27 cm) above the bottom of the fuel tank or cell. This location is ideal to allow sediment to fall to the bottom of the tank or cell without it being drawn into the fuel system.

f. Fuel Gage Provision (Fig. 4-2). A provision usually is made to install a fuel gage. This provision usually is in the form of a flanged hole.

g. Drainplug (Fig. 4-2). A threaded drainplug usually is provided at the bottom of the tank for draining and cleaning.

4-2. Fuel Filters.

a. Purpose. The fuel filter traps foreign material that may be present in the fuel and preventing it from entering the carburetor or sensitive fuel injection components.

b. Location (Fig. 4-5). There is at least one fuel filter used in the fuel system. A fuel filter can be located in any accessible place along the fuel delivery line. Filters also can be located inside fuel tanks, carburetors, and fuel pumps.

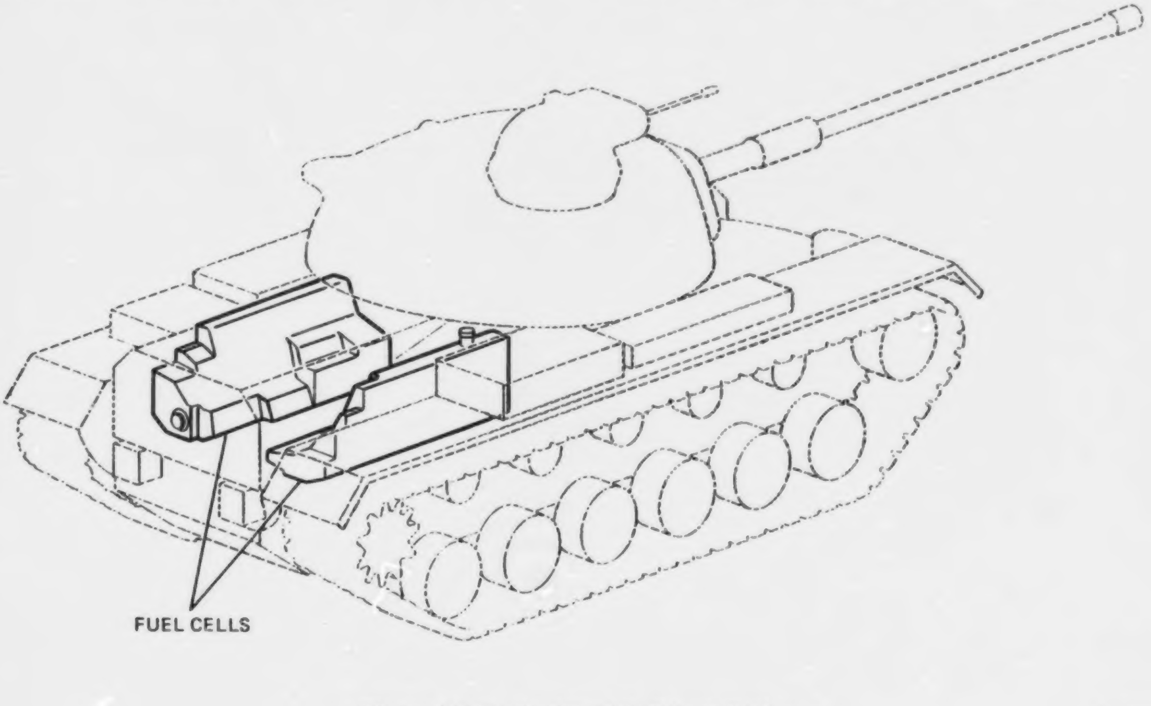


Figure 4-3. Typical Fuel Cell Installation.

TA233387

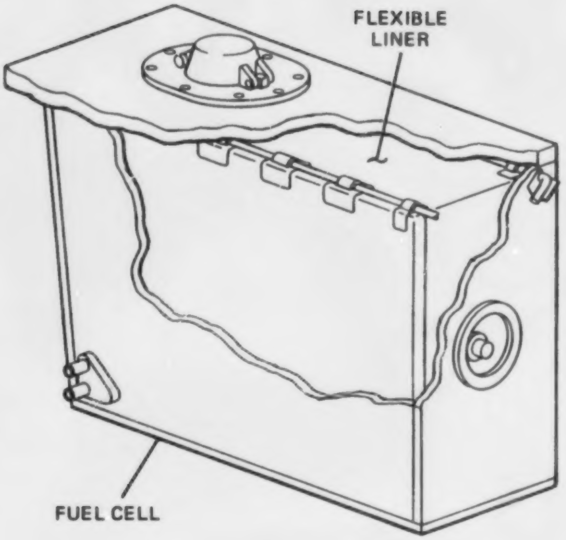

FLEXIBLE LINER
FUEL CELL

Figure 4-4. Bladder-Type Fuel Cell.

c. Operation (Fig. 4-6). Fuel filters operate by passing the fuel through a porous filtering medium. The openings in the porous material are very small and, as a result, any particles in the fuel that are large enough to cause problems are blocked. In addition to the filtering medium, the filter in most cases also serves as a sediment bowl. The gasoline, as it passes through the filter, spends enough time in the sediment bowl to allow large particles and water to settle out of it.

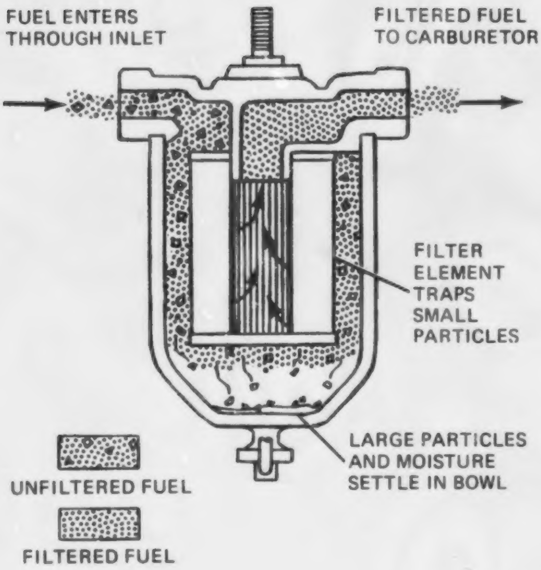

FUEL ENTERS THROUGH INLET
FILTERED FUEL TO CARBURETOR
FILTER ELEMENT TRAPS SMALL PARTICLES
LARGE PARTICLES AND MOISTURE SETTLE IN BOWL
UNFILTERED FUEL
FILTERED FUEL

Figure 4-6. Fuel Filter Operation.

d. Fuel Filter Configurations. The various types of fuel filters are:

(1) *Replaceable In-Line Filter (A, Fig. 4-7).* This type of filter is periodically replaced. The body of the filter acts as a sediment bowl.

(2) *In-line Filter Elements that Fit in the Carburetor Inlet or Inside the Fuel Tank on the*

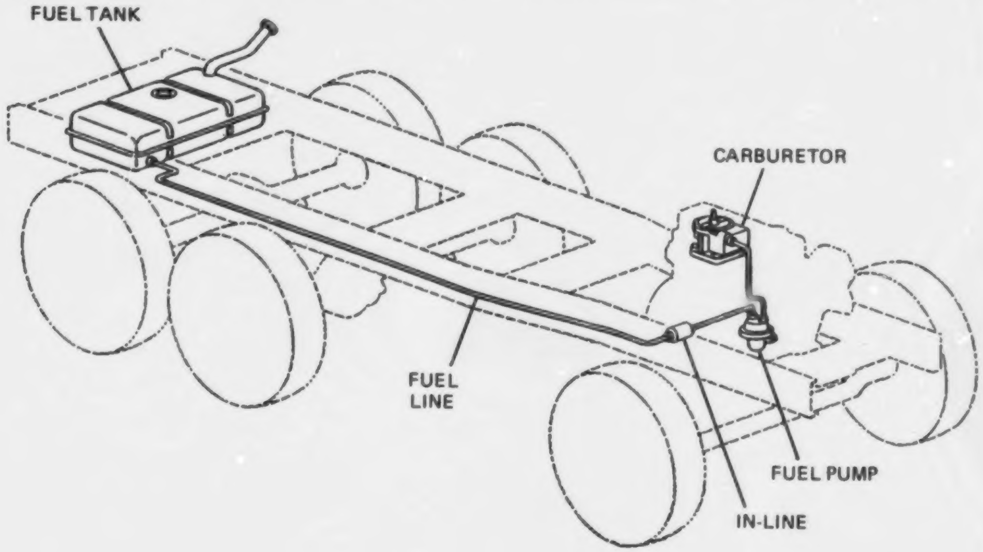
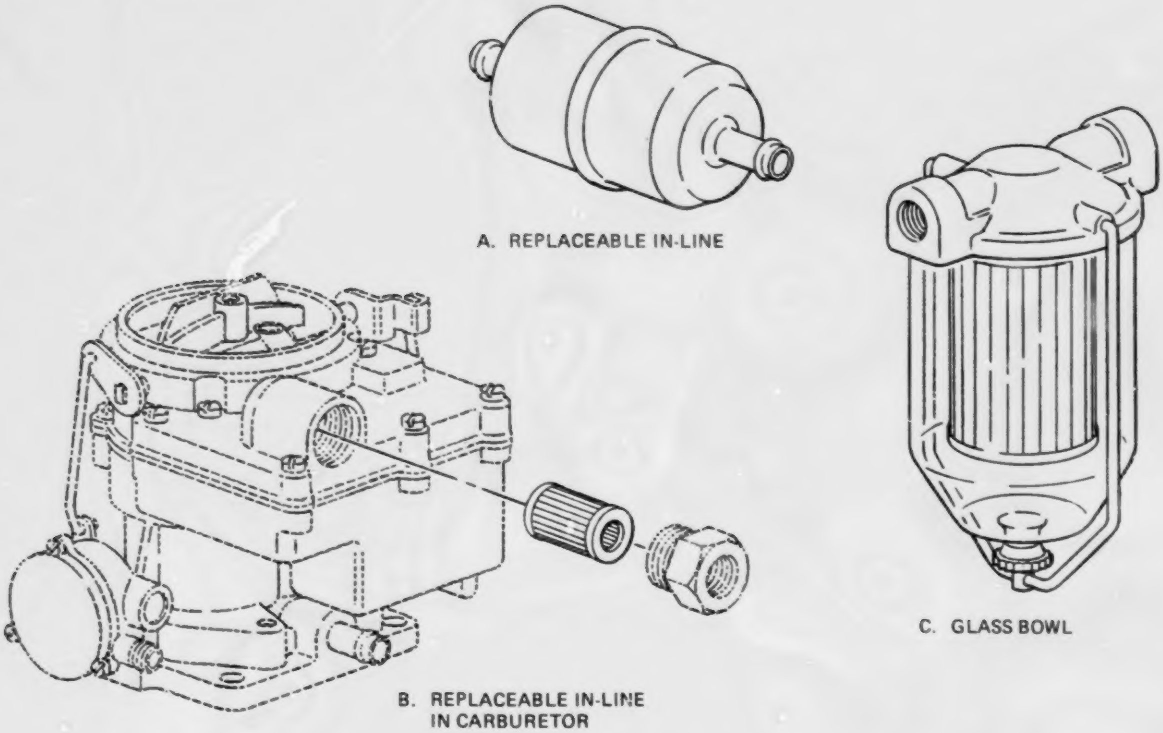

FUEL TANK
CARBURETOR
FUEL LINE
FUEL PUMP
IN-LINE

Figure 4-5. Typical Fuel Filter Locations.

TA233388


A. REPLACEABLE IN-LINE

B. REPLACEABLE IN-LINE IN CARBURETOR

C. GLASS BOWL

Figure 4-7. Fuel Filter Configurations.

Outlet (B, Fig. 4-7). These filters are replaceable at intervals and contain no sediment bowls.

(3) *Glass Bowl Filter with Replaceable Element (C, Fig. 4-7).* The sediment bowl must be washed out whenever the element is replaced. Some fuel pumps have a glass bowl-type gas filter built in.

e. Element Configurations (Fig. 4-8). Filter elements are made from ceramic, treated paper, sintered bronze, or metal screen. There is one filter element that differs from the others. It consists of a pile of laminated disks that are spaced 0.0003 in. (0.0076 mm) apart. As the gasoline passes between the disks, foreign matter is blocked out.

4-3. Fuel Pumps.

a. Purpose. The fuel pump delivers gasoline from the fuel tank to the engine. Early automotive equipment utilized gravity to feed gasoline to the engine. This is no longer practical because it limits the location of the fuel tank to positions that are above the engine.

b. General. The mechanical-type fuel pump generally is the most popular for gasoline engine applications. It usually is more than adequate and is much cheaper than an electric pump. The electric pump is more desirable though, for the following reasons.

(1) The electric pump will supply fuel to the engine immediately when the ignition key is turned on. The engine must be turning with the starter for a mechanical pump to operate.

(2) The pump, by design, will operate more efficiently if it pushes the fuel rather than pulling it. An electric pump can be mounted close to the tank, or in the tank, to take advantage of this characteristic.

(3) The electric pump can be mounted away from heat to reduce the possibility of vapor lock (para 4-37).

c. Mechanical, Nonpositive Type (Fig. 4-9). This is currently the most popular configuration of an automotive fuel pump. Operation is as follows:

TA233389

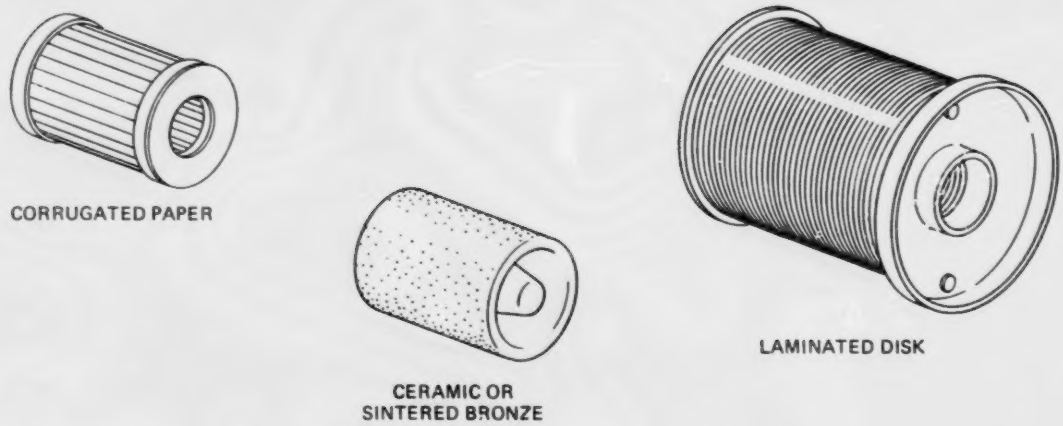


Figure 4-8. Fuel Filter Element Configurations.

(1) The rocker arm is moved up and down by the engine camshaft. The rocker arm spring causes the rocker arm to follow the cam lobe.

(2) The rocker arm hooks into an elongated slot in the pull rod. The other end of the pull rod is attached to the diaphragm.

(3) As the camshaft operates the rocker arm, it will operate the diaphragm against the force of the diaphragm spring.

(4) As the rocker arm pulls the diaphragm down, the inlet check valve is unseated and fuel is drawn into the pump chamber. The outlet check valve seals the outlet passage.

(5) As the diaphragm spring pushes the diaphragm back up, the inlet check valve seals the inlet and the fuel in the pump chamber is pushed through the unseated outlet check valve and through the pump outlet.

(6) The action is repeated each time the rocker arm operates the diaphragm.

(7) Pressure will build in the fuel line and the pump chamber as the fuel pump fills the carburetor bowl. As the pressure rises to the desired level in the pump chamber, it will hold the diaphragm down against the pressure of the diaphragm spring. The rocker arm will move up and down in the slotted pull rod. There will be no pumping action until the fuel line pressure again drops below the desired level. In this way, the nonpositive-type fuel pump regulates fuel line pressure. Normal pressures range from 1.5 to 6 psi (10.3 to 41.4 kPa). The operating range of the pump depends on the tension exerted by the diaphragm spring.

(8) A venthole is provided under the diaphragm to allow the pressure to change in the lower chamber as the diaphragm flexes.

(9) The pulsation chamber, located above the pump chamber, uses a soft diaphragm and a sealed chamber to cushion the pulsating action inherent to the diaphragm-type pump.

(10) An oil seal is provided to keep crankcase oil from entering the lower chamber and leaking from the venthole.

d. Mechanical, Positive Type (Fig. 4-10). The positive-type mechanical pump operates in the same manner as the nonpositive type. The difference is that the diaphragm pull rod is solidly linked to the rocker arm. The pump, therefore, will not regulate fuel line pressure. When this type of pump is used, a separate fuel pressure regulation device must be used that will bypass excess fuel back to the fuel tank.

e. Double Action Fuel Pump (Fig. 4-11). Vehicles that use vacuum-operated windshield wipers often will utilize a supply pump that is built into the fuel pump. The pump serves to operate the windshield wipers during periods of high engine load when manifold vacuum is low (para 17-14). The pump operates from the same

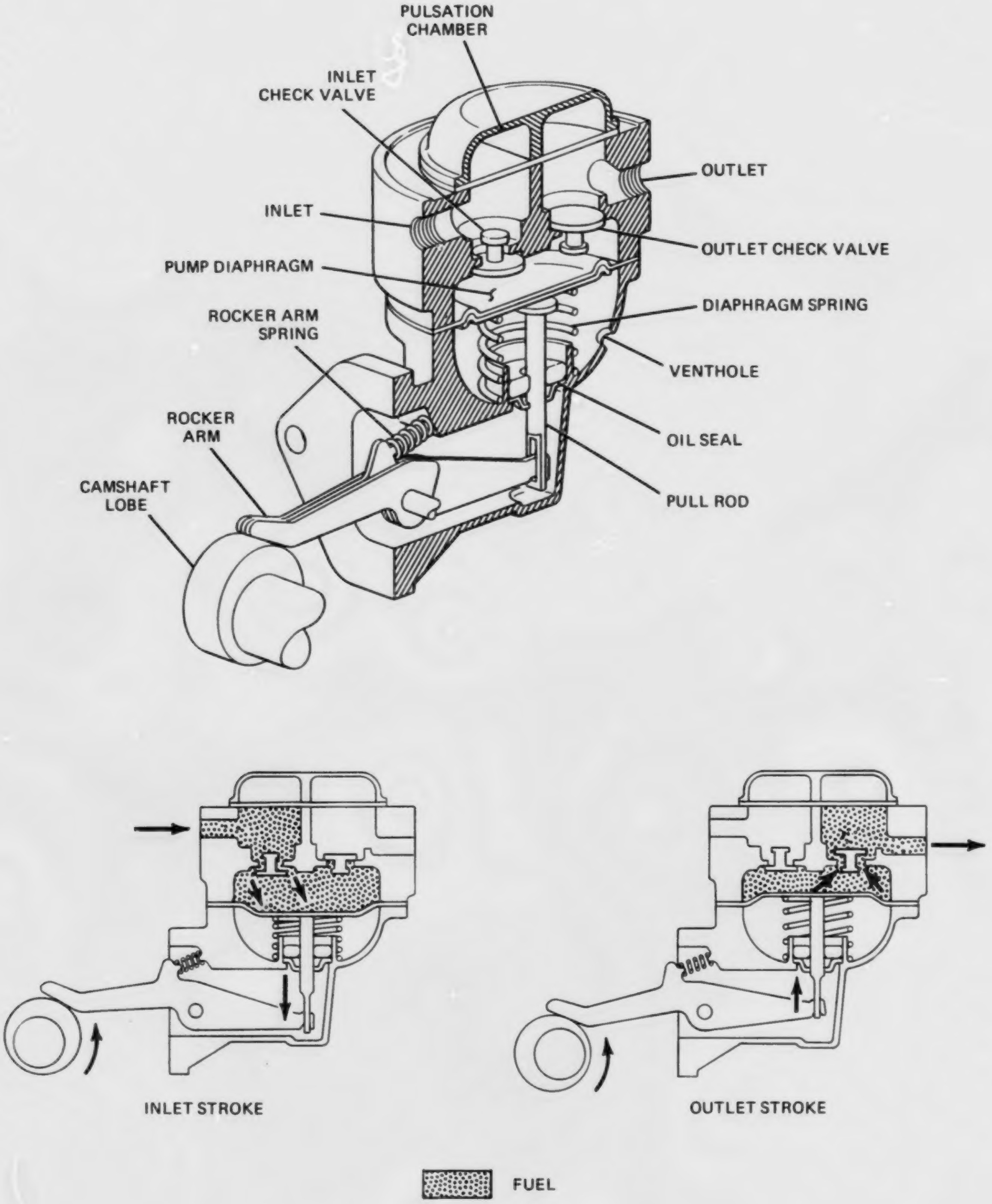

PULSATION CHAMBER
INLET CHECK VALVE
OUTLET
INLET
OUTLET CHECK VALVE
PUMP DIAPHRAGM
DIAPHRAGM SPRING
ROCKER ARM SPRING
VENTHOLE
ROCKER ARM
OIL SEAL
CAMSHAFT LOBE
PULL ROD
INLET STROKE
OUTLET STROKE
FUEL

Figure 4-9. Mechanical Nonpositive Pump.

TA233391

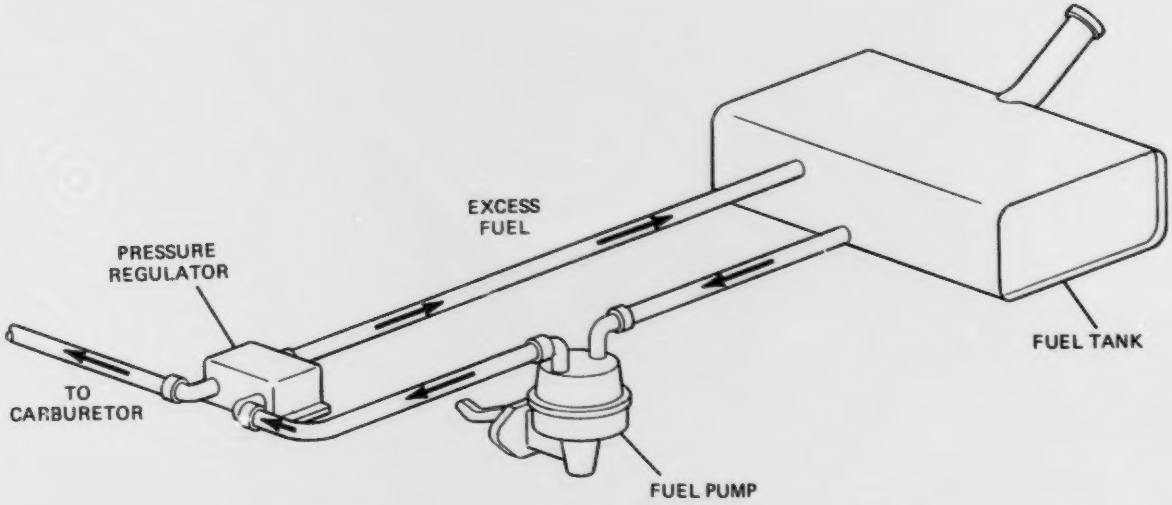

EXCESS FUEL
PRESSURE REGULATOR
FUEL TANK
TO CARBURETOR
FUEL PUMP

Figure 4-10. Mechanical Positive Pump Installation.

rocker arm as the fuel pump and is a nonpositive-type diaphragm pump. At times when manifold vacuum alone is sufficient to operate the windshield wipers, the diaphragm will be held up against the diaphragm spring by atmospheric pressure, rendering the pump inoperative.

f. Electric, Bellows-Type (Fig. 4-12). The bellows-type electric fuel pump works basically the same as the nonpositive-type mechanical pump. The difference is that it is driven by an electric solenoid rather than a mechanical camshaft. Operation is as follows:

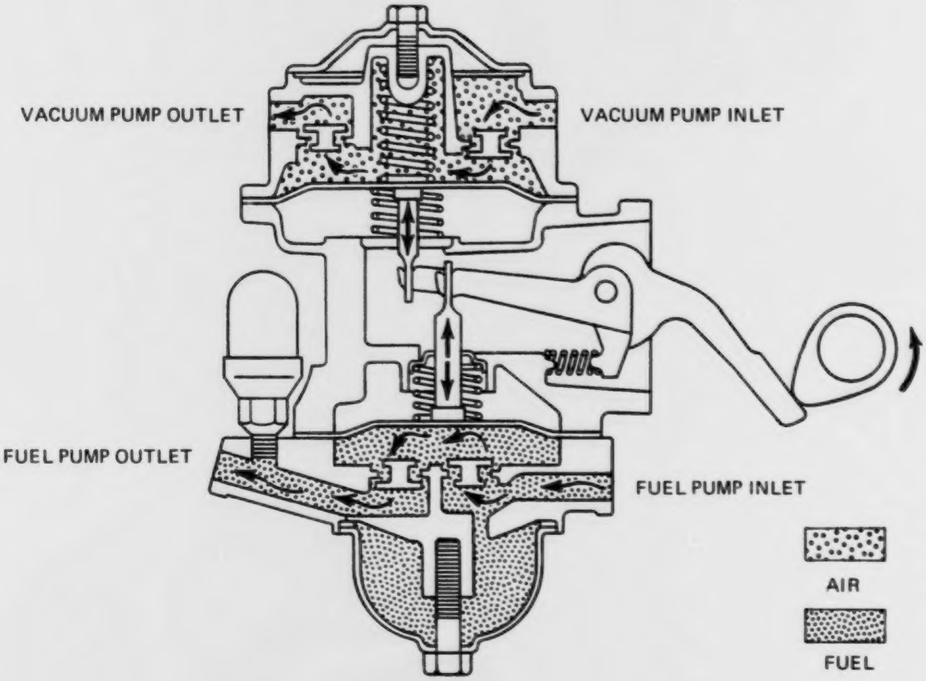

VACUUM PUMP OUTLET
VACUUM PUMP INLET
FUEL PUMP OUTLET
FUEL PUMP INLET
AIR
FUEL

Figure 4-11. Double Action Pump.

TA233392

86

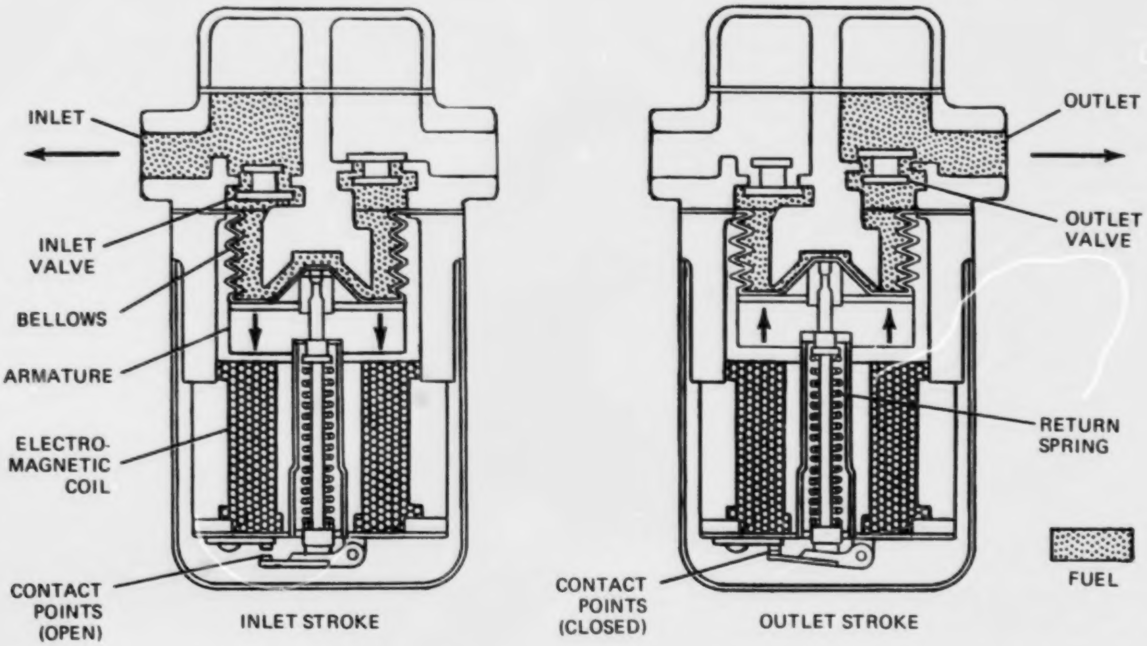

INLET
INLET VALVE
BELLOWS
ARMATURE
ELECTRO-MAGNETIC COIL
CONTACT POINTS (OPEN)
INLET STROKE
OUTLET
OUTLET VALVE
RETURN SPRING
FUEL
CONTACT POINTS (CLOSED)
OUTLET STROKE

Figure 4-12. Bellows-Type Electric Fuel Pump.

(1) As electric current is fed to the pump, the electromagnetic coil pulls the armature down, expanding the bellows.

(2) The expansion of the bellows causes fuel to be drawn in through the inlet valve.

(3) As the bellows are fully expanded, a pair of contact points are open, switching off the electromagnet.

(4) The return spring pushes the armature back up, contracting the bellows. This action pushes the fuel out of the pump through the outlet valve.

(5) The contact points are closed as the bellows are fully contracted. This causes the electromagnet to pull the armature down and repeat the pumping process.

(6) The pump will stop when the fuel pressure is high enough to hold the bellows expanded against the return spring. The operating pressure of the pump is determined by the return spring pressure.

g. Electric, Vane-Type (Fig. 4-13). The vane-type electric fuel pump operates by the same principles as the pump described in paragraph 20-6. It is driven by an electric motor.

4-4. Fuel Tank Ventilation Systems.

a. Purpose. The fuel tank needs a ventilation system to keep the pressure within it equal to

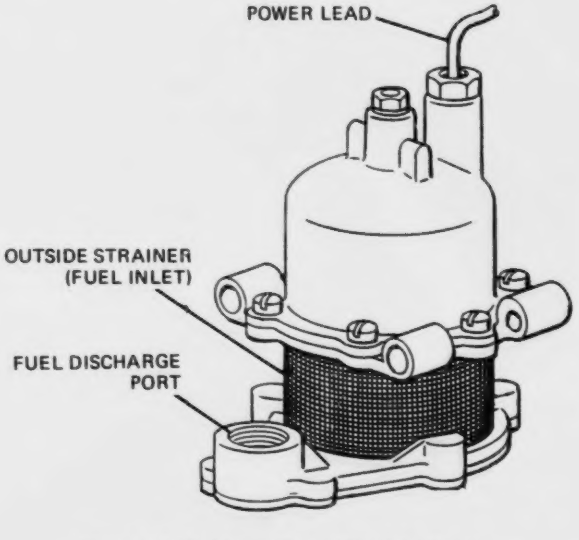

POWER LEAD
OUTSIDE STRAINER (FUEL INLET)
FUEL DISCHARGE PORT

Figure 4-13. Vane-Type Electric Pump.

TA233393

atmospheric pressure. This is important for the following reasons:

(1) Air must be allowed to enter the tank as the fuel is pumped out. Without ventilation of the tank, the pressure in the tank would drop to the point where the fuel pump would not be able to draw any more fuel from it. In some cases, the higher pressure around the outside of the tank could cause it to collapse.

(2) Temperature changes cause the fuel in the tank to expand and contract. Absence of a ventilation system could cause excessive or insufficient fuel line pressure.

b. Configurations. The most common methods of venting a fuel tank are:

(1) By venting the fuel tank cap to the atmosphere. This method was the most common on earlier passenger cars and trucks. It still is used on vehicles that are not subject to emission control regulations or used for fording.

(2) By providing a line to the fuel tank that vents the fuel tank at a point that is high enough to prevent water from entering during fording operations.

(3) Vehicles that are subject to emission control regulations have fuel tank ventilation systems that work in conjunction with the evaporation control system. This system is discussed in paragraph 7-5.

4-5. Intake Manifold.

a. Description (Fig. 4-14). The intake manifold should:

(1) Deliver the mixture to the cylinders in equal quantities and proportions. This is important for smooth engine performance. The lengths of the passages should be as near to equal as possible to distribute the mixture equally.

(2) Help to keep the vaporized mixture from condensing before it reaches the combustion chamber. Because the ideal mixture should be vaporized completely as it enters the combustion chamber, this is very important. To reduce the condensing of the mixture, the manifold passages should be designed with smooth walls and a minimum of bends that collect fuel. Smooth flowing intake manifold passages also increase volumetric efficiency (para 2-23).

(3) Aid in the vaporization of the mixture. To do this, the intake manifold should provide a controlled system of heating (para 7-3). This system of heating must heat the mixture enough to aid in vaporization without heating to the point of significantly reducing volumetric efficiency (para 2-23).

b. Ram Induction (Fig. 4-15). Intake manifolds can be designed to provide optimum performance for a given engine speed range by varying the length of the passages. The inertia of the moving intake mixture will cause it to bounce back and forth in the manifold passage from the end of one intake stroke to the beginning of the next intake stroke. If the passage is the proper length so that the next intake stroke is just beginning as the mixture is rebounding, the inertia of the mixture will cause it to ram itself into the cylinder. This will increase the volumetric efficiency of the engine in the designated speed range. It should be noted that the ram manifold

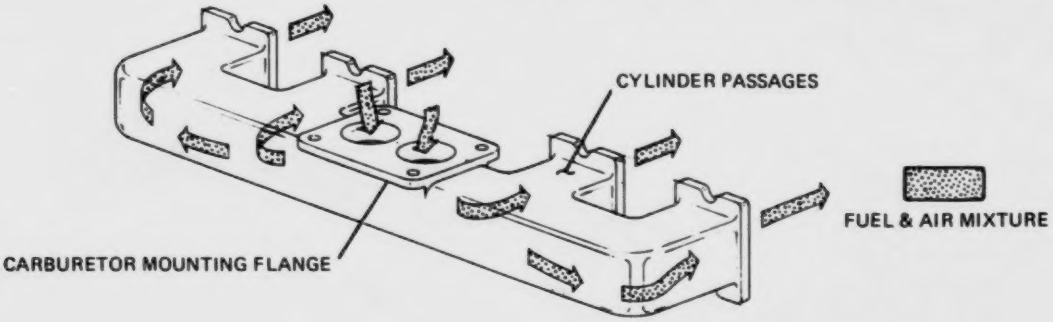


Figure 4-14. Typical Intake Manifold.

TA233394

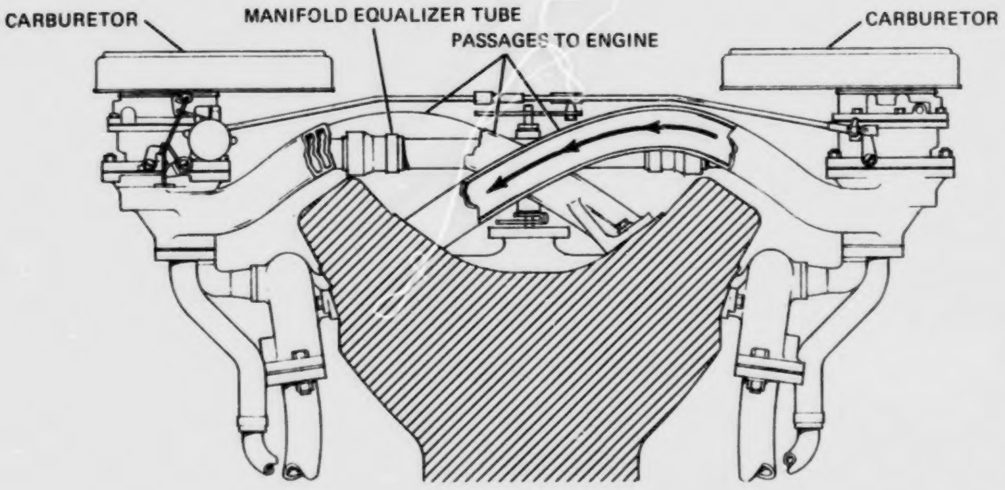


Figure 4-15. Ram Induction Manifold.

will serve no useful purpose outside of its designated speed range.

c. Heating the Mixture. As stated in paragraph 4-5a(3), providing controlled heat for the incoming mixture is very important for good performance. The heating of the mixture may be accomplished by doing one or both of the following:

(1) Directing a portion of the exhaust through a passage in the intake manifold (fig. 4-16). The heat from the exhaust will transfer and heat the mixture. The amount of exhaust that is diverted into the intake manifold heat passage is controlled by the manifold heat control valve. Its operation is covered in paragraph 7-3.

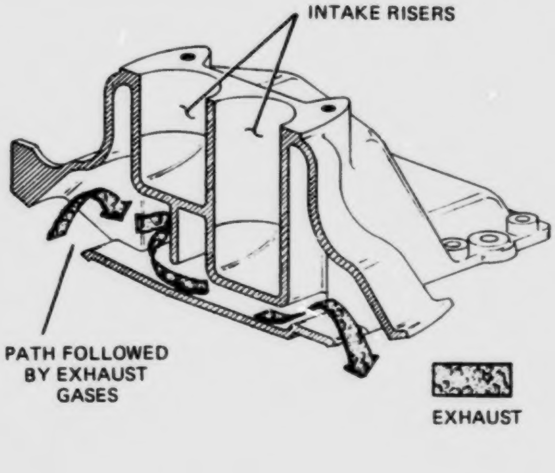


Figure 4-16. Exhaust-Heated Intake Manifold.

(2) Directing the engine coolant, which is laden with engine heat, through the intake manifold on its way to the radiator (fig. 4-17).

4-6. Air Filters.

a. Purpose (Fig. 4-18). The air filter fits over the engine air intake to filter out any foreign matter. Any foreign matter that enters the intake will act as an abrasive between the cylinder walls and the pistons, greatly shortening engine life. The two types of filters currently in use are the wet and dry type.

b. Wet Type (Fig. 4-19). The wet-type, or the oil bath, air filter consists of the main body, the filter element that is made of woven copper gauze, and the cover. Operation is as follows: The incoming air enters between the cover and the main body. It is pulled down to the bottom of the main body, where it must make a 180-degree turn as it passes over the oil reservoir. As the air passes over the oil reservoir, most of the particles will not be able to make the turn, they will hit the oil and be trapped. As the air continues upward and passes through the filter element, the smaller particles that bypassed the oil will be trapped. The air keeps the filter element soaked with oil by creating a fine spray as it passes the reservoir. The air then makes another 180-degree turn and enters the carburetor.

TA233395

c. Dry Type (Fig. 4-20). The dry-type air filter passes the incoming air through a filtering medium before it enters the engine. The filtering medium consists of oil-soaked copper mesh or replaceable pleated paper, the latter being the most common.

4-7. Carburetor. The carburetor will be discussed, system by system, in paragraphs 4-13 thru 4-24. It serves the following basic functions:

a. The carburetor mixes fuel and air into the correct proportions for the most efficient use by the engine. The carburetor also must constantly vary the mixture proportions to meet the engine's needs as its speed and load requirements vary.

b. The carburetor regulates engine speed and power output.

c. The carburetor atomizes the fuel as it mixes it with the air (para 4-9e).

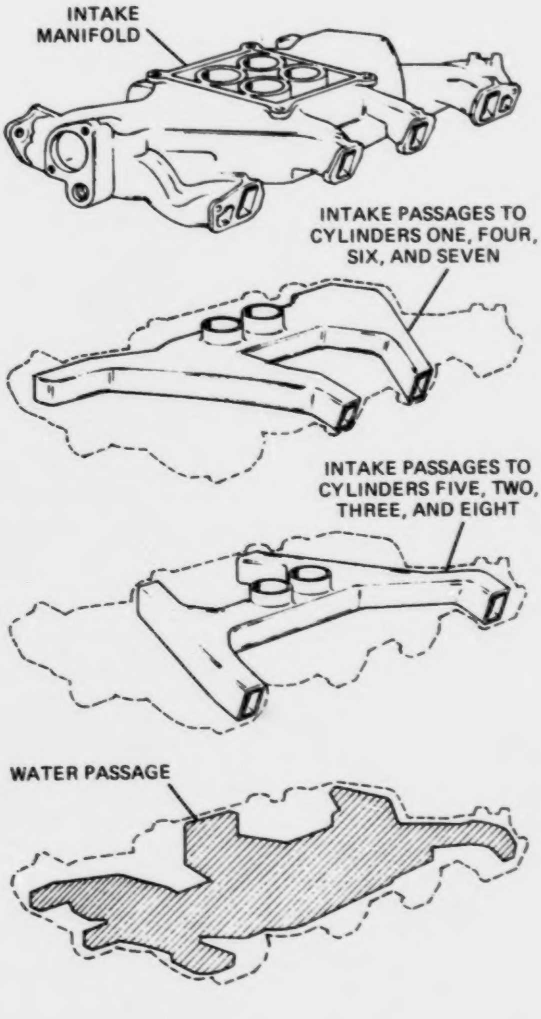

INTAKE MANIFOLD
INTAKE PASSAGES TO CYLINDERS ONE, FOUR, SIX, AND SEVEN
INTAKE PASSAGES TO CYLINDERS FIVE, TWO, THREE, AND EIGHT
WATER PASSAGE

Figure 4-17. Water-Heated Intake Manifold.

TA233396

20

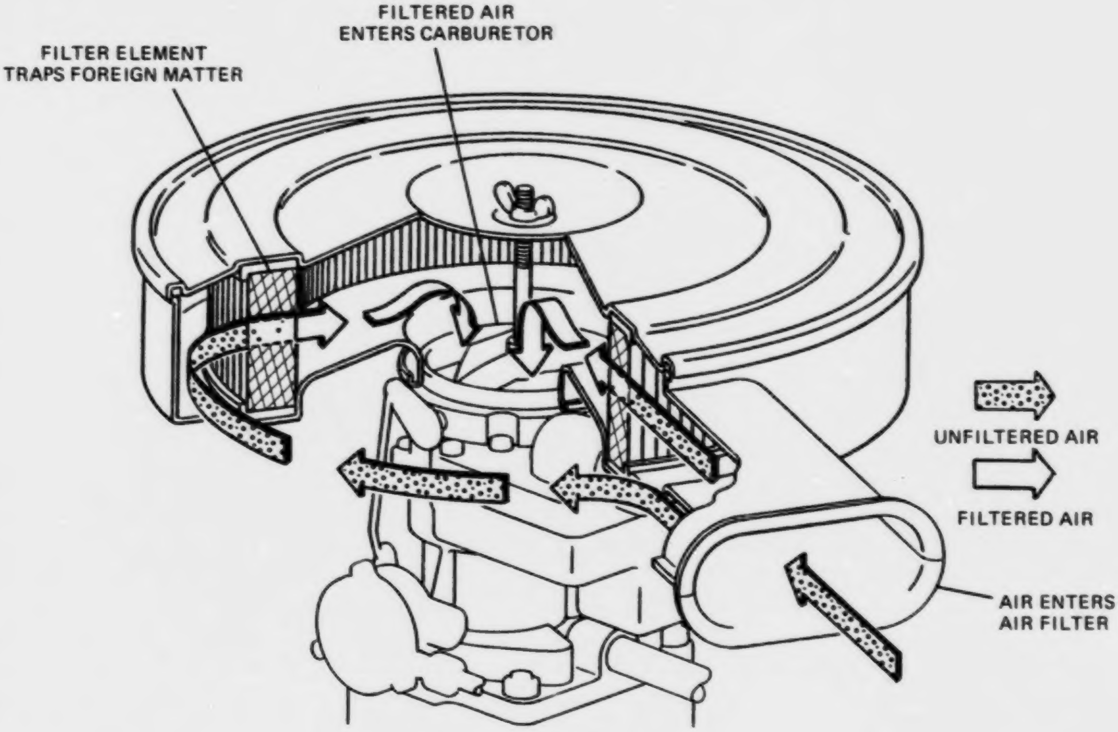

FILTERED AIR ENTERS CARBURETOR
FILTER ELEMENT TRAPS FOREIGN MATTER
UNFILTERED AIR
FILTERED AIR
AIR ENTERS AIR FILTER

Figure 4-18. Air Filter.

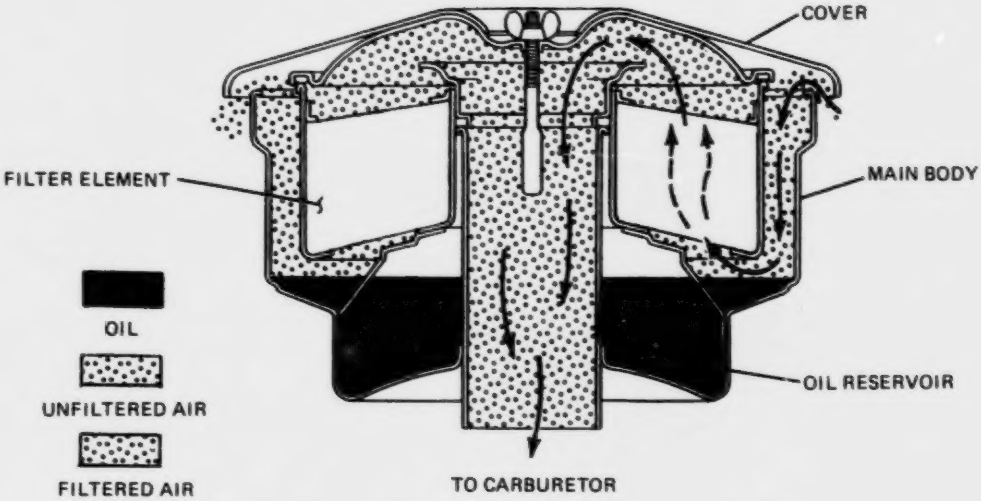
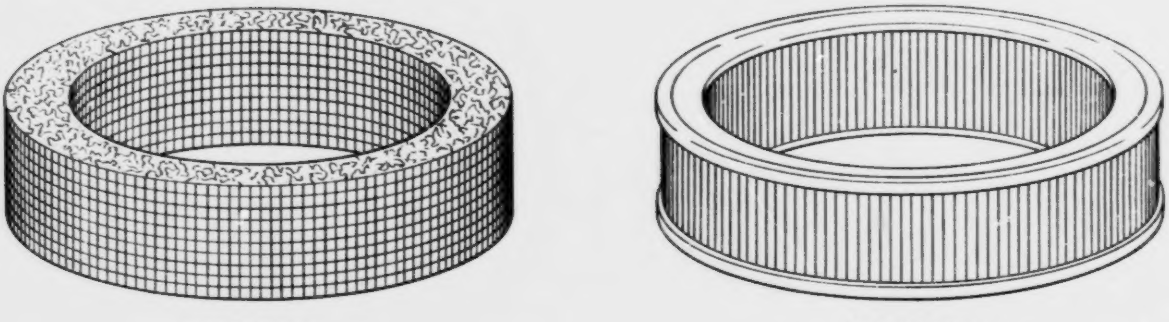

COVER
FILTER ELEMENT
MAIN BODY
OIL
UNFILTERED AIR
FILTERED AIR
OIL RESERVOIR
TO CARBURETOR

Figure 4-19. Wet-Type Air Filter.

TA233397

91


COPPER MESH

PLEATED PAPER

Figure 4-20. Dry-Type Air Filter.

Section II. PRINCIPLES OF CARBURETION

4-8. Composition of Air. Air is composed of various gases, mostly nitrogen and oxygen (78 percent nitrogen and 21 percent oxygen by volume). These gases, as are all substances, are made of tiny particles called molecules. In the air surrounding the earth, as in all gases, the molecules are able to move quite freely in relation to each other. The molecules of air are attracted to the earth by gravity, creating the atmosphere (para 2-22a). The weight of the air molecules creates atmospheric pressure (para 2-22b).

4-9. Evaporation. Evaporation is the changing of a liquid to a vapor. The molecules of the liquid, not being closely tied together, are constantly moving about among themselves. Any molecule that moves upward with sufficient speed will jump out of the liquid and into the air. This process will cause the liquid to evaporate over a period of time. The rate of evaporation is dependent on the following:

a. *Temperature.* The rate of movement of the molecules increases with temperature. Because of this, the amount of molecules leaving the liquid for a given time will increase as the temperature increases.

b. *Atmospheric Pressure.* As atmospheric pressure increases, the amount of air molecules present over the liquid also increases. The increased presence of air molecules will slow the rate of evaporation. This is because the molecules of liquid will have more air molecules to collide with. In many cases, they will fall back into the liquid after collision.

c. *Closed Chamber.* As evaporation takes place in a closed container, the space above the liquid will reach a point of saturation. When this happens, every molecule of liquid that enters the air will cause another airborne molecule of liquid to fall back.

d. *Volatility.* The term volatility refers to how fast a liquid vaporizes. Some liquids vaporize easily at room temperature. Alcohol, for instance, vaporizes more easily than water. A highly volatile liquid is one that is considered to evaporate easily.

e. *Atomization (Fig. 4-21).* Atomization is the process of breaking up a liquid into tiny globules or droplets. When a liquid is atomized, the droplets are all exposed individually to the air. For this reason, atomization greatly increases evaporation by increasing the exposed surface area of the liquid.

4-10. Venturi Effect (Fig. 4-22). Venturi effect is used by the carburetor to mix gasoline with air. The basic carburetor has an hourglass-shaped tube called a throat. The most constricted part of the throat is called the venturi. A tube called a discharge nozzle is positioned in the venturi. The discharge nozzle is connected to a reservoir of gasoline called the float bowl. The negative pressure that exists in the combustion chamber because of the downward intake stroke of the piston causes atmospheric pressure to create an airflow through the carburetor throat. This airflow must increase temporarily in speed as it passes through the venturi, due to its decreased size.

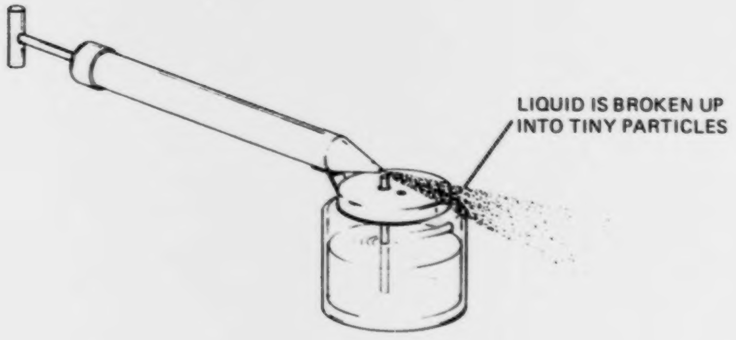

LIQUID IS BROKEN UP INTO TINY PARTICLES

Figure 4-21. Example of Atomization.

The increased speed of the airflow also will result in a corresponding decrease in pressure within the venturi and at the end of the discharge nozzle. When this occurs, atmospheric pressure will push gasoline through the discharge nozzle and into the carburetor throat, where it will mix with the intake airflow.

4-11. The Basic Carburetor (Fig. 4-22). The ideal state for the fuel to be in when it reaches the cylinder is to be vaporized completely. Good intake manifold design will help to vaporize the fuel, but the carburetor must properly atomize the fuel beforehand. Atomization of the fuel occurs as it is drawn into the venturi. As the fuel comes out of the discharge nozzle, it is broken into tiny droplets as it enters the airflow. To ensure that there is a high degree of atomization, a tiny hole called an air bleed is used to allow air to mix with the fuel in the discharge tube. The fuel is then further atomized as it enters the venturi. To ensure proper fuel flow, a secondary venturi or a venturi booster may be used (fig. 4-23). It will decrease further the pressure at the discharge nozzle.

4-12. Air-Fuel Ratio (Fig. 4-24). The proportions of an air-fuel mixture are expressed in terms of the air-fuel ratio. It is the relationship by weight of the mixture. An example of how this is expressed would be:

Air-Fuel Ratio = 12:1.

In this air-fuel mixture, the air would be 12 times as heavy as the fuel. The operational range of air-fuel ratios in an average gasoline engine are from approximately 9:1 to approximately 17:1. Air-fuel ratios on the lower end (less air) are considered to be rich mixtures while the air-fuel ratios at the higher end (more air) are considered

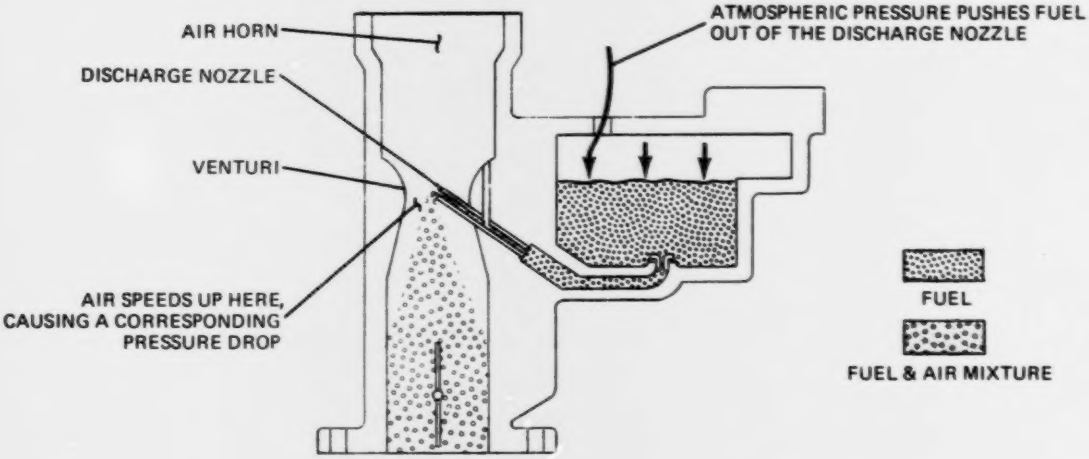

AIR HORN
DISCHARGE NOZZLE
VENTURI
AIR SPEEDS UP HERE, CAUSING A CORRESPONDING PRESSURE DROP
ATMOSPHERIC PRESSURE PUSHES FUEL OUT OF THE DISCHARGE NOZZLE
FUEL
FUEL & AIR MIXTURE

Figure 4-22. Venturi Effect.

TA233399

93

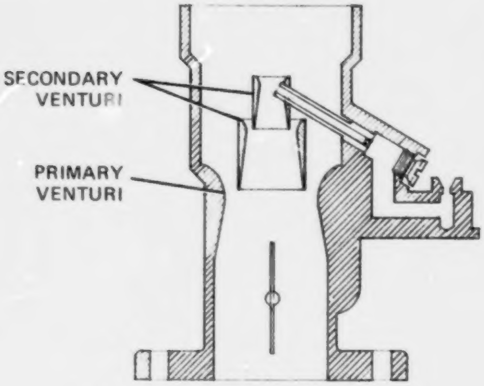


Figure 4-23. Secondary Venturi.

to be lean mixtures. A gasoline engine, propelling a vehicle at a steady speed, operates on an air-fuel ratio of approximately 15:1. Considering that gasoline weighs approximately 640 times as much as air, it can be seen that a gasoline engine consumes a tremendous amount of air. If, in fact, the air-fuel ratio was considered by volume rather than weight, it would be seen that a gasoline engine operating on an air-fuel ratio of 15:1 consumes approximately 9600 gallons of air for every gallon of gasoline.

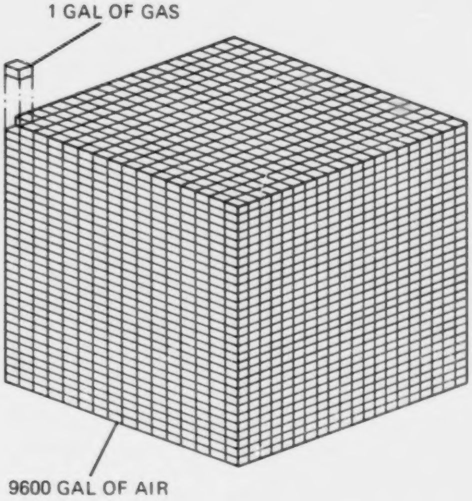


Figure 4-24. Air-Fuel Ratio Demonstration.

Section III. CONSTRUCTION OF THE BASIC CARBURETOR

4-13. Throttle Valve (Fig. 4-25). The throttle valve is used to regulate the speed and power output of the engine. It is controlled by the accelerator pedal, and usually consists of a flat, round plate that tilts with the throttle shaft. As the accelerator pedal is fully depressed, the throttle valve is moved from a position of completely restricting the throat to being completely open. The idle stop screw is used to keep the throttle valve open slightly so that the engine may run at a regulated idle speed with no foot pressure on the accelerator. This screw may be turned in or out to regulate engine idle speed.

4-14. Float Circuit.

a. Purpose. The float circuit maintains a steady working supply of gasoline at a constant level in the carburetor. This is very critical to proper engine performance. An excessively high float level will cause fuel to flow too freely from the discharge tube, causing an overly rich mixture; whereas an excessively low float level will cause an overly lean mixture.

b. Operation (Fig. 4-26). As explained in paragraph 4-3, the fuel pump delivers gasoline to

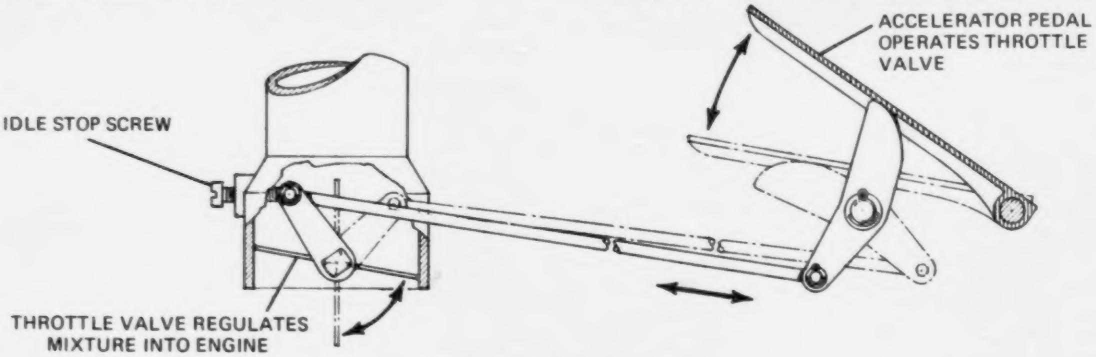

ACCELERATOR PEDAL OPERATES THROTTLE VALVE
IDLE STOP SCREW
THROTTLE VALVE REGULATES MIXTURE INTO ENGINE

Figure 4-25. Throttle Valve.

TA233400

94

BEST COPY AVAILABLE

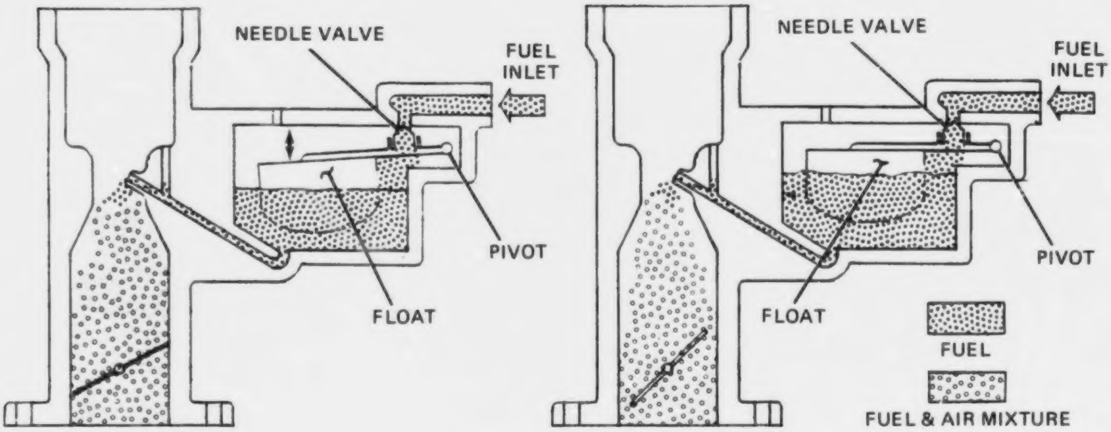

NEEDLE VALVE
FUEL INLET
PIVOT
FLOAT
NEEDLE VALVE
FUEL INLET
PIVOT
FLOAT
FUEL
FUEL & AIR MIXTURE

Figure 4-26: Float Circuit.

the fuel pump under pressure to the carburetor. The following events occur as the gasoline enters the carburetor through the fuel inlet:

(1) The gasoline begins to fill the float bowl.

(2) The float rises with the level of the gasoline.

(3) The needle valve is closed by the rising float as the fuel reaches the desired level in the float bowl.

(4) As the engine uses the gasoline from the float bowl, the level will drop. This will cause the float to drop, which will open the needle valve to let in more fuel.

c. *Venting (Fig. 4-27).* The pressure in the float bowl must be regulated to assure the proper delivery of fuel and purging of vapors. The following systems and devices are added to the float circuit system to provide for these needs.

(1) *Balance Tube.* Due to the restriction imposed by the air filter and changing air velocities because of varying engine speeds, the air pressure in the air horn is usually lower than atmospheric pressure. The pressure in the float bowl must equal that of the air horn in order for the carburetor to provide fuel delivery. A tube called a balance tube is run between the air horn and the float bowl to accomplish this task.

(2) *Idle Vent.* Because gasoline is highly volatile, it can create overly rich mixtures during

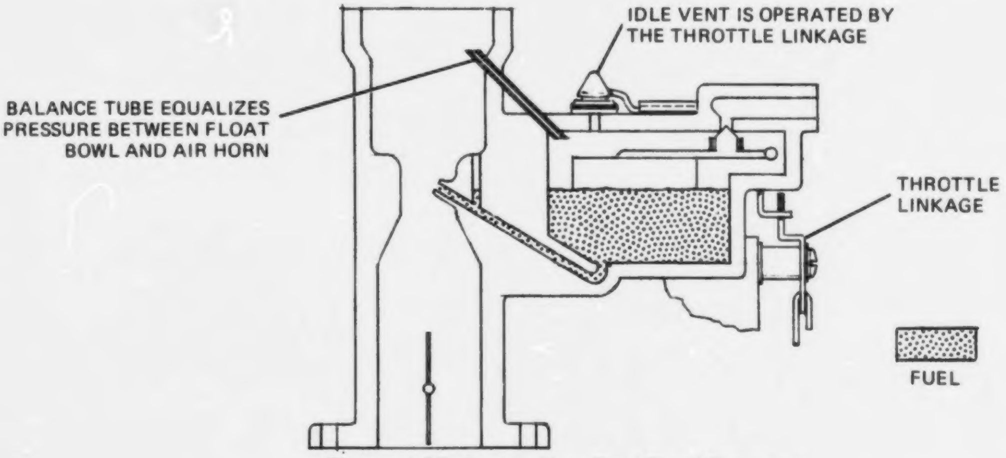

IDLE VENT IS OPERATED BY THE THROTTLE LINKAGE
BALANCE TUBE EQUALIZES PRESSURE BETWEEN FLOAT BOWL AND AIR HORN
THROTTLE LINKAGE
FUEL

Figure 4-27. Controlling Fuel Bowl Pressure.

TA233401

long periods of engine idle. This is because the fuel begins to evaporate in the float bowl and the vapors get into the air horn through the balance tube. The solution to this problem is to have an outside vent for the float bowl that is opened whenever the engine is idling. The idle vent is activated by linkage from the throttle valve. The idle vent system on later vehicles may be part of the emission control system (para 7-11).

Section IV. SYSTEMS OF THE CARBURETOR

4-15. General. The two operating systems of the carburetor each contain two circuits that give them the flexibility to operate throughout the entire engine speed range. Both of these systems obtain gasoline from the float bowl through the main jet (fig. 4-28). The main jet is a precisely sized opening that helps govern the amount of fuel used. The main jet usually is replaceable and is available in a variety of sizes. Carburetors can be tailored to meet various needs by varying jet sizes. In addition to the above, the carburetor must provide other systems to compensate for temperature change and for quick changes in throttle position.

4-16. Idle and Low-Speed System.

a. Purpose. The idle and low-speed system provides the proper air-fuel mixture when the engine is at idle and during periods of small throttle opening. During these periods, there is not enough air flowing through the throat to make the discharge nozzle work.

b. Operation (Fig. 4-29). The idle and the low-speed portions of the system are really separate circuits in operation. The idle circuit sustains the engine at an idle. As the throttle begins to open, the effectiveness of the idle circuit falls off gradually as the low-speed circuit takes over. The transition between the two circuits is a smooth one. Operation from engine idle through low-speed range is as follows:

(1) The throttle valve is almost closed at engine idle. This creates a high vacuum in the area of the carburetor under the throttle valve. This high vacuum causes atmospheric pressure to push gasoline through the idle port from the float bowl. The gasoline mixes with the air that is drawn in around the throttle valve. The mixture then is drawn into the engine.

(2) As the throttle valve is opened, the vacuum under it begins to fall off, causing less gasoline to be drawn from the idle port. As more air flows through the throat, the gasoline will begin flowing through the low speed or off-idle discharge port, which is usually in the shape of a rectangular slot or a series of two or three holes. During the low-speed system operation, there is still not enough airflow through the throat for the discharge nozzle to work.

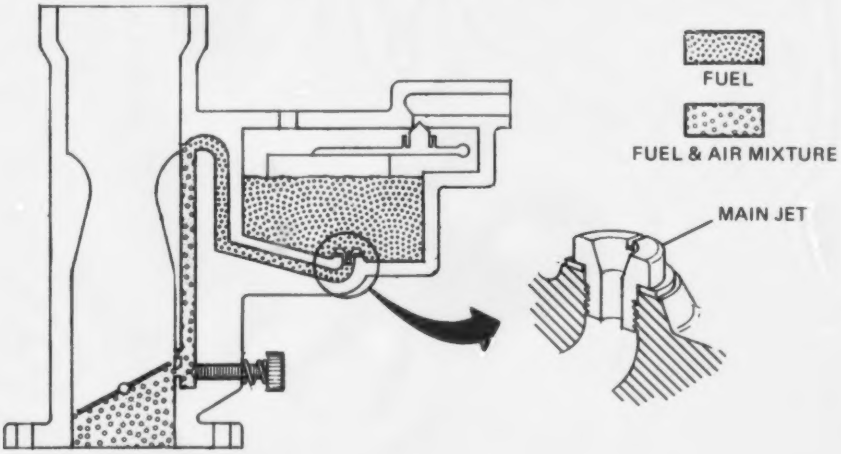


Figure 4-28. Main Jet.

TA233402

96

BEST COPY AVAILABLE

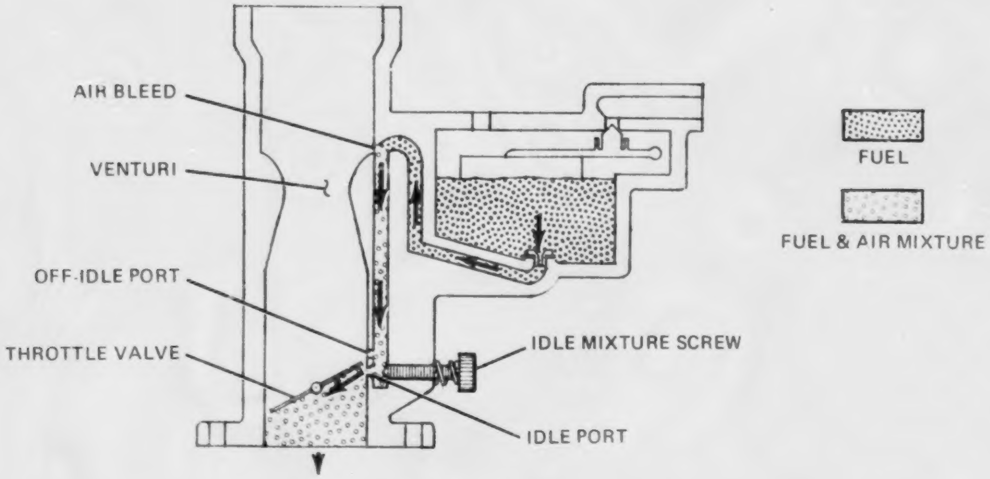


Figure 4-29. Idle and Low-Speed Systems.

c. Idle Mixture Screw (Fig. 4-29). A needle-shaped screw is used in the carburetor to regulate the idle port opening. The air-fuel ratio of the idle system can be adjusted by turning the screw in or out.

d. Air Bleeds (Fig. 4-29). Air bleeds also are used in the idle and low-speed circuits to help atomize the fuel.

e. Passage to Float Bowl (Fig. 4-29). The passage that supplies the idle and low-speed circuits must at some point be higher than the level of the gasoline in the float bowl. If this passage went straight to the idle and low-speed ports, the float bowl would be able to drain through them.

4-17. High-Speed and High-Speed Enrichment Circuits.

a. Purpose. The high-speed circuit supplies the fuel-air mixture to the engine during medium to full throttle valve opening. The high-speed circuit gradually will take over from the low-speed circuit as the throttle is depressed. The carburetor is designed to provide approximately a 15:1 to 17:1 air-fuel ratio under normal steady speed conditions. The high-speed enrichment circuit will enrich the mixture to approximately 11:1 to 12:1 if a heavy demand is placed on the engine.

b. Operation (Fig. 4-30). The high-speed circuit takes its gasoline from the float bowl through the main jet. The gasoline is fed through a passageway to the discharge nozzle, where it mixes with the air in the venturi. Opening the throttle valve and accelerating engine speed increases the airflow in the venturi, which causes a proportional increase in the amount of gasoline from the discharge nozzle. The high-speed enrichment system increases the fuel flow to the discharge nozzle by either increasing the main jet opening or providing a second supply of fuel from the float bowl. There are three basic high-speed enrichment systems that are covered in paragraphs 4-17c, d, and e.

c. Power Jet (Fig. 4-31). The power jet system includes a jet that is opened by a vacuum-operated piston. The jet provides an extra supply of fuel to the discharge nozzle from the float bowl. When the throttle valve is not opened wide, there will be high manifold vacuum because the carburetor throat is restricted. This high manifold vacuum is used to hold the vacuum piston against its spring. When the piston is up, the spring in the power jet will hold it closed. The throttle valve is opened when extra power is demanded, causing a drop in manifold vacuum. As manifold vacuum drops, the spring on the vacuum piston pushes the piston down, which in turn pushes the power valve open. The power jet sometimes is referred to as the economizer and the vacuum piston is referred to as the step-up or power piston.

d. Vacuum-Operated Metering Rod (Fig. 4-32). The vacuum-operated metering rod uses a rod with a diameter that gets progressively

TA233403

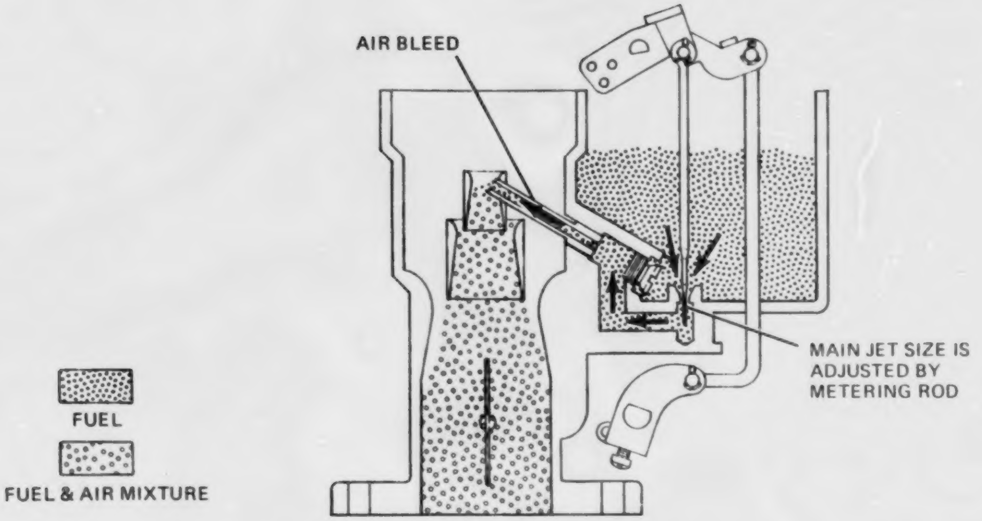

AIR BLEED
MAIN JET SIZE IS ADJUSTED BY METERING ROD
FUEL
FUEL & AIR MIXTURE

Figure 4-30. High-Speed Systems.

larger in steps from its end. The vacuum piston, which works the same way as the one in paragraph 4-17c, operates the metering rod. When the engine load is light and manifold vacuum is high, the piston pushes the metering rod into the jet against spring pressure, restricting the flow to the discharge tube. When the load demand increases, the manifold vacuum decreases, causing the

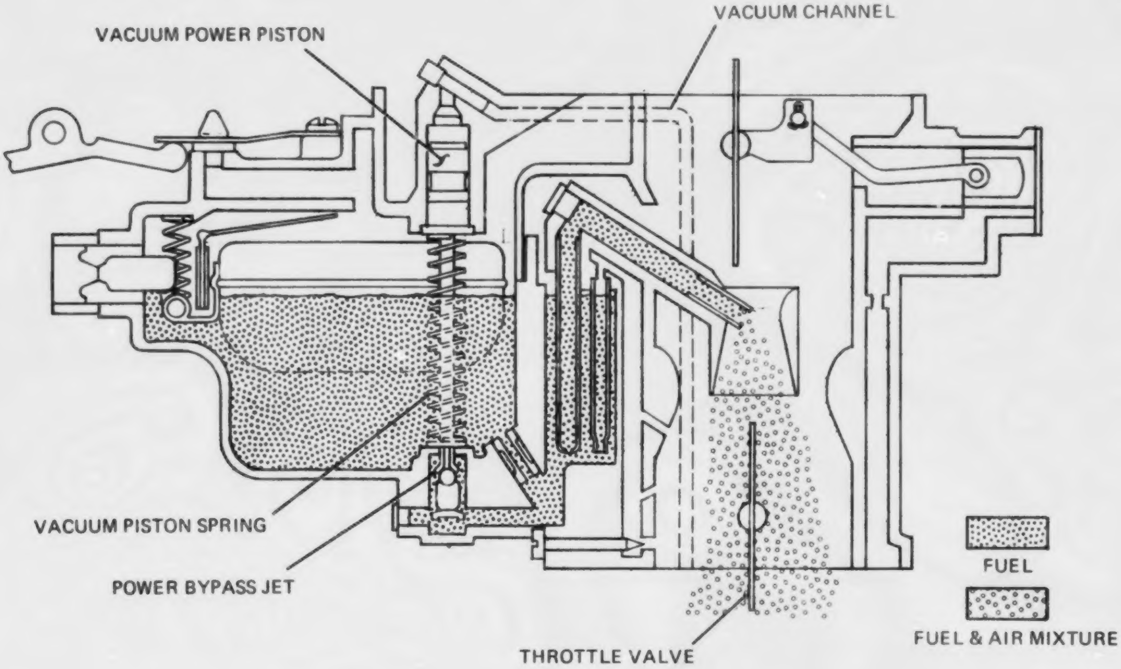

VACUUM POWER PISTON
VACUUM CHANNEL
VACUUM PISTON SPRING
POWER BYPASS JET
THROTTLE VALVE
FUEL
FUEL & AIR MIXTURE

Figure 4-31. Vacuum Power Jet.

TA233404

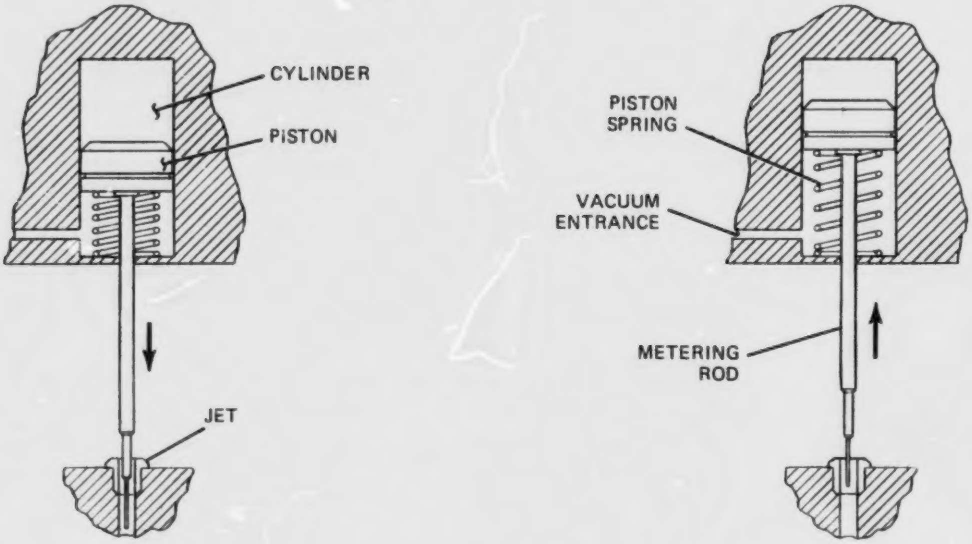

CYLINDER
PISTON
JET
PISTON SPRING
VACUUM ENTRANCE
METERING ROD

Figure 4-32. Vacuum-Operated Metering Rod.

piston spring to lift the metering rod out of the jet, progressively increasing the fuel flow to the discharge tube.

e. Mechanically Operated Metering Rod (Fig. 4-33). The mechanically operated metering rod works by the same principles as the vacuum-operated one described in paragraph 4-17d with the exception that it is operated by linkage from the throttle valve. The linkage is calibrated so that the metering rod regulates the fuel perfectly for each throttle position.

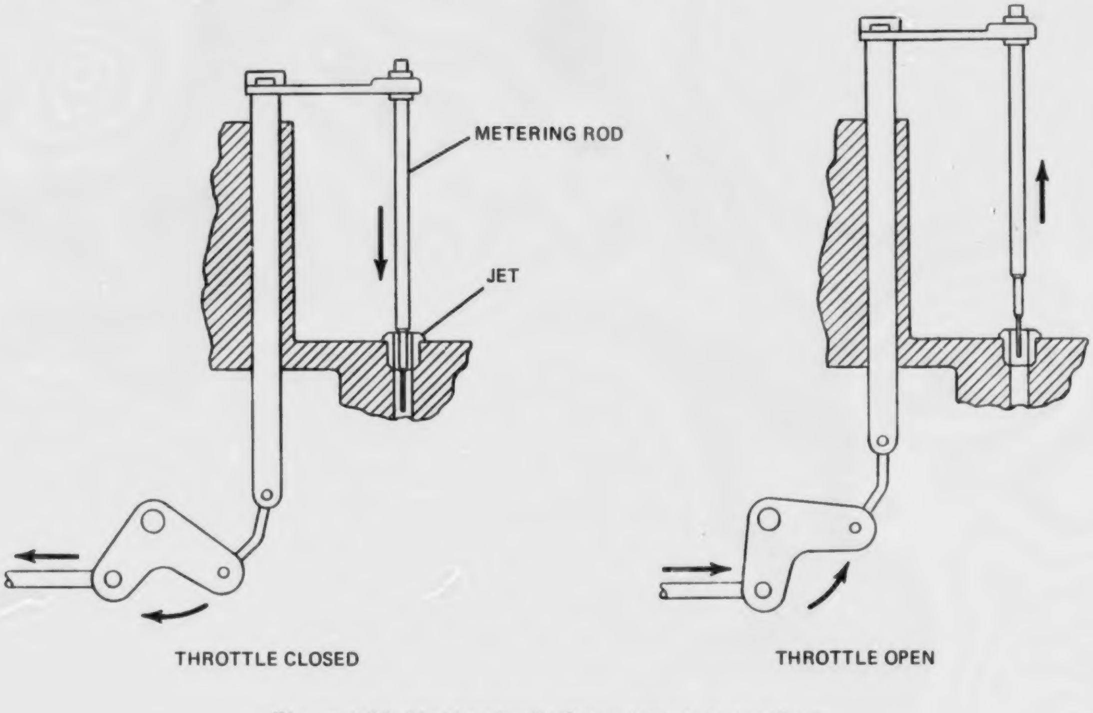

METERING ROD
JET
THROTTLE CLOSED
THROTTLE OPEN

Figure 4-33. Mechanically Operated Metering Rod.

TA233405

99

4-18. Accelerator Pump Circuit.

a. Purpose. When the throttle valve suddenly is opened, there is a corresponding sudden increase in the speed of the airflow through the carburetor. Because the air is lighter than the gasoline, it will accelerate quicker, causing a very lean mixture to reach the engine for a brief period. This would result in a severe lag in engine performance if not for the accelerator pump circuit. Its job is to inject a measured charge of gasoline into the carburetor throat whenever the throttle valve is opened.

b. Operation (Fig. 4-34). The accelerator pump circuit consists of a pump that is operated by linkage directly from the throttle valve. There are passageways that connect the pump to the float bowl and pump discharge nozzle. There are two check valves in the system to control the direction of gasoline flow. Operation is as follows:

(1) The pump is pushed down in the pump chamber as the throttle valve is opened, forcing gasoline through the outlet passageway.

(2) The inlet check valve will seat, keeping gasoline from being pumped back to the float bowl.

(3) The outlet check ball will be forced off of its seat, allowing the gasoline to pass to the pump discharge nozzle where it will be discharged into the throat.

(4) The pump is raised in the chamber when the throttle valve is closed, causing the outlet check ball to seat, blocking the passageway.

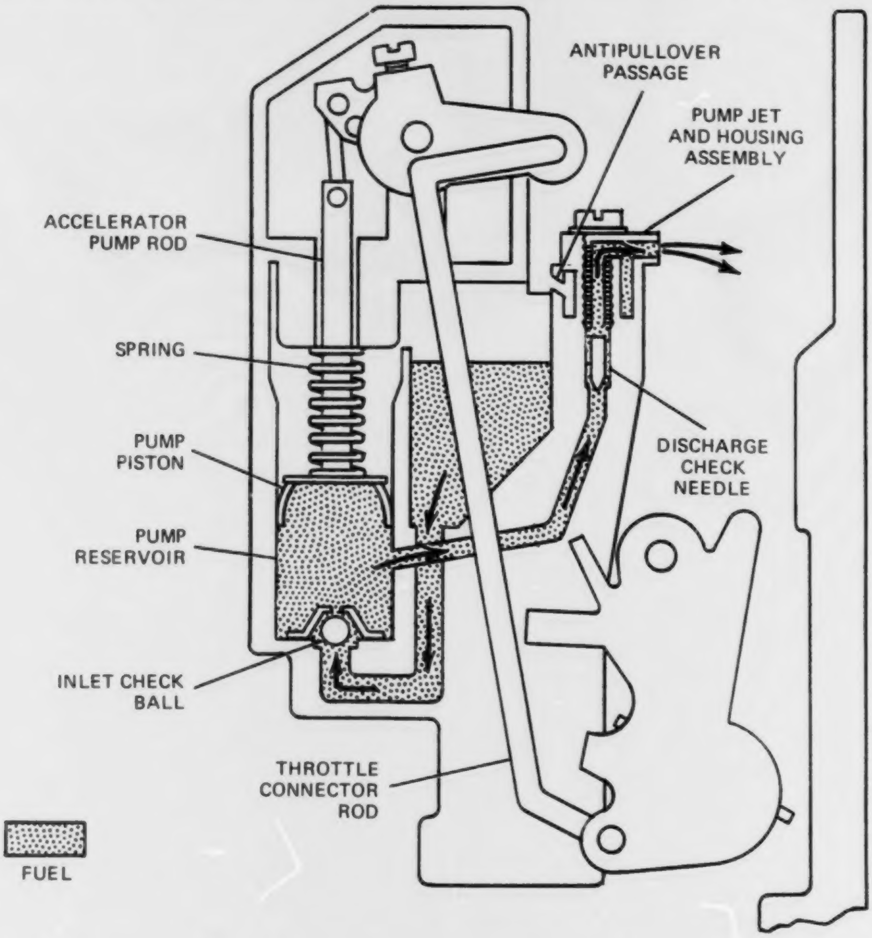

ANTIPULLOVER PASSAGE
PUMP JET AND HOUSING ASSEMBLY
ACCELERATOR PUMP ROD
SPRING
PUMP PISTON
DISCHARGE CHECK NEEDLE
PUMP RESERVOIR
INLET CHECK BALL
THROTTLE CONNECTOR ROD
FUEL

Figure 4-34. Accelerator Pump Circuit.

TA233406

(5) The inlet check ball is pulled off of its seat and gasoline is pulled into the chamber from the float bowl.

(6) The pump chamber is filled with gasoline and ready to discharge whenever the throttle valve is opened.

c. Diaphragm Pump (Fig. 4-35). The diaphragm-type pump system works just like the piston type with the exception of the pump design, which is a flat rubber diaphragm. By flexing this diaphragm, a pressure differential is created that results in pump action.

d. Controlling Pump Discharge (Fig. 4-36). The linkage between the accelerator pump and the throttle cannot be solid. If it were, the pump would act as a damper, not allowing the throttle to be opened and closed readily. The linkage usually activates the pump through a slotted shaft or something similar. When the throttle is closed, the pump is held up by its linkage. When the throttle is opened, the pump is activated by being pushed down by a spring that is called a duration spring. The tension of the duration spring controls the length of time that the injection of fuel lasts. The spring is calibrated to specific applications. Too much spring pressure will cause fuel to be discharged too quickly, resulting in reduced fuel economy. Too little spring pressure will cause fuel to be discharged too slowly, resulting in engine hesitation.

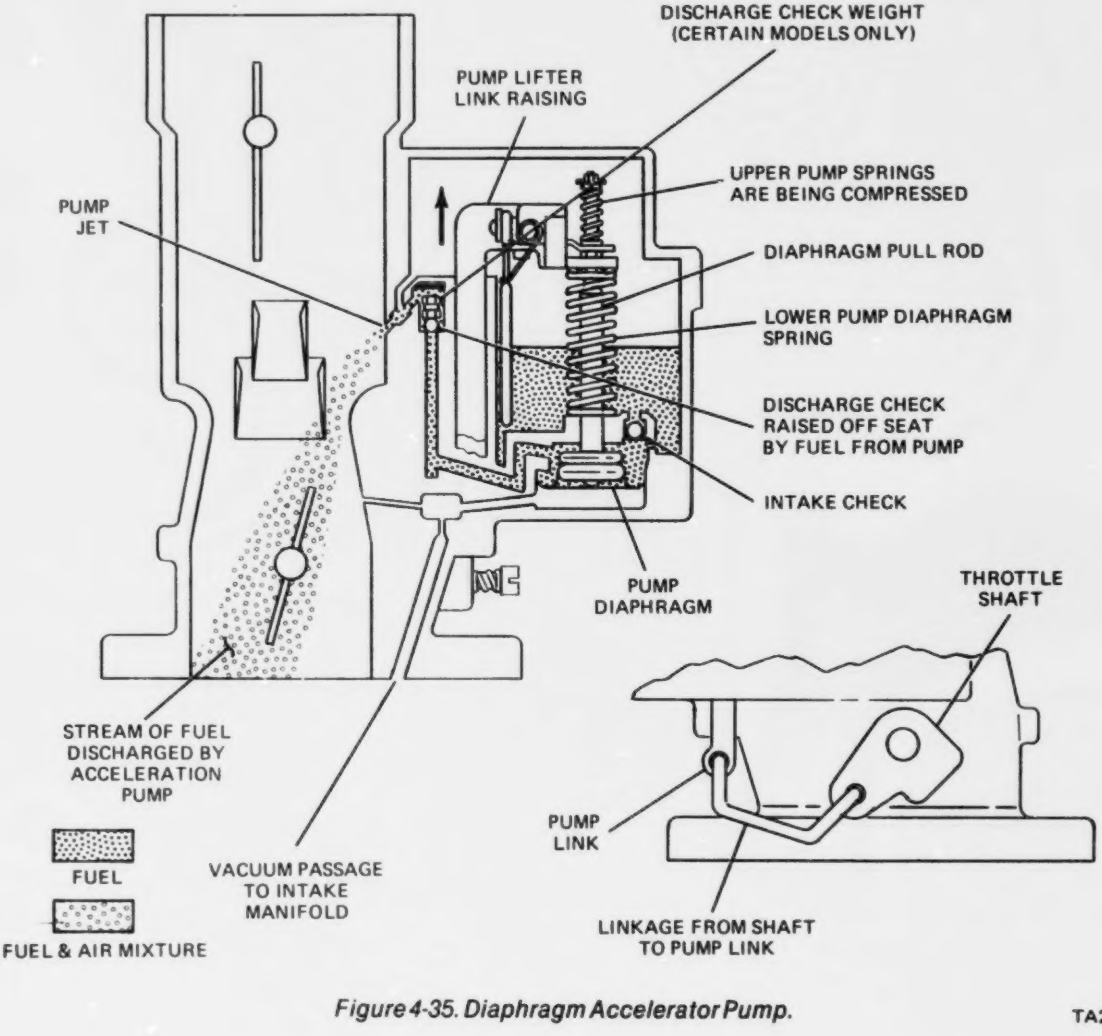
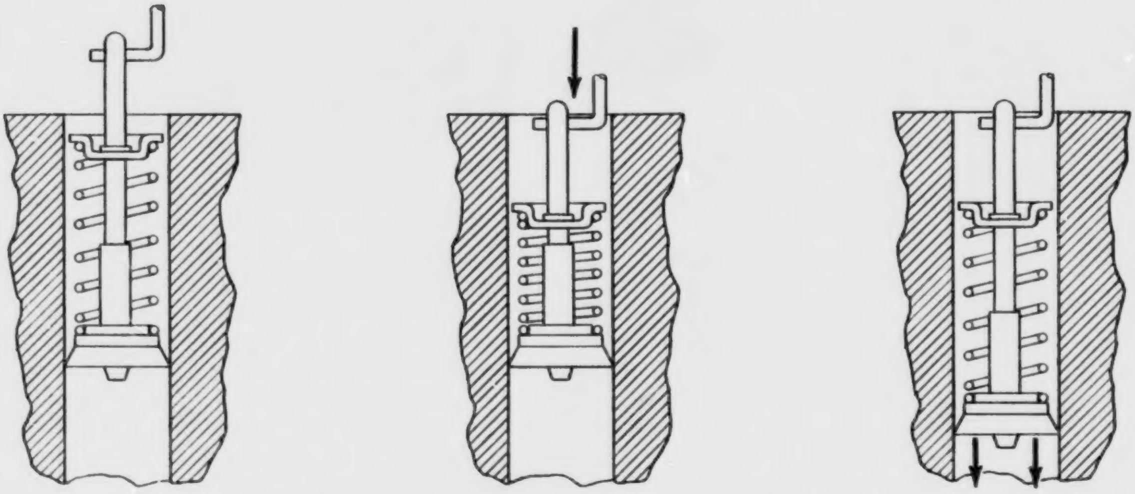

DISCHARGE CHECK WEIGHT (CERTAIN MODELS ONLY)
PUMP LIFTER LINK RAISING
UPPER PUMP SPRINGS ARE BEING COMPRESSED
PUMP JET
DIAPHRAGM PULL ROD
LOWER PUMP DIAPHRAGM SPRING
DISCHARGE CHECK RAISED OFF SEAT BY FUEL FROM PUMP
INTAKE CHECK
PUMP DIAPHRAGM
THROTTLE SHAFT
STREAM OF FUEL DISCHARGED BY ACCELERATION PUMP
PUMP LINK
FUEL
VACUUM PASSAGE TO INTAKE MANIFOLD
FUEL & AIR MIXTURE
LINKAGE FROM SHAFT TO PUMP LINK

Figure 4-35. Diaphragm Accelerator Pump.

TA233407



ACCELERATOR PEDAL UP

ACCELERATOR PEDAL PUSHED DOWN

DURATION SPRING DISCHARGES FUEL

Figure 4-36. Duration Spring.

4-19. Choke System.

a. Purpose. When the engine is cold, the gasoline tends to condense into large drops in the manifold rather than vaporizing. By supplying a richer mixture (8:1 to 9:1), there will be enough vapor to assure complete combustion. The carburetor is fitted with a choke system to provide this richer mixture. The choke system provides a very rich mixture to start the cold engine. It then gradually makes the mixture less rich as the engine reaches operating temperature.

b. Operation (Fig. 4-37). The choke system consists of a flat plate that restricts the throat above the venturi but is located below the balance tube so that it has no affect on the pressure in the float bowl. This plate is called a choke valve, and, like the throttle valve, is mounted on a shaft to tilt it opened or closed.

c. Manual Choke System (Fig. 4-38). The manually operated choke used to be the most popular way of controlling the choke valve. Due to emission regulations, the possible danger in use with catalytic converters (para 7-8), and technological advances in automatic choke systems, manual choke systems are little used today. The choke valve is operated by a flexible cable that extends into the driver's compartment. As the control is pulled out, the choke valve will be closed so that the engine can be started. As the control is pushed back in, the position of the choke valve is adjusted to provide the proper mixture. The following are two features that are incorporated into manual choke systems to reduce the possibility of engine flooding by automatically admitting air into the engine:

(1) A spring-loaded poppet valve that is automatically pulled open by the force of the engine intake strokes.

(2) A choke valve that is pivoted off center on its shaft. This will create a pressure differential between the two sides of the choke valve when it is subjected to the engine intake, causing it to be pulled open against the force of spring-loaded linkage.

d. Automatic Choke System (Fig. 4-39). The automatic choke control system is centered around a thermostatic coil spring. The spring exerts pressure to hold the choke valve closed. Heat is applied to the coil after the engine is started. The heat causes the coil to expand, allowing the choke to open.

e. Providing Automatic Choke Heat. The four methods of providing controlled heat to the automatic choke thermostatic spring are:

TA233408

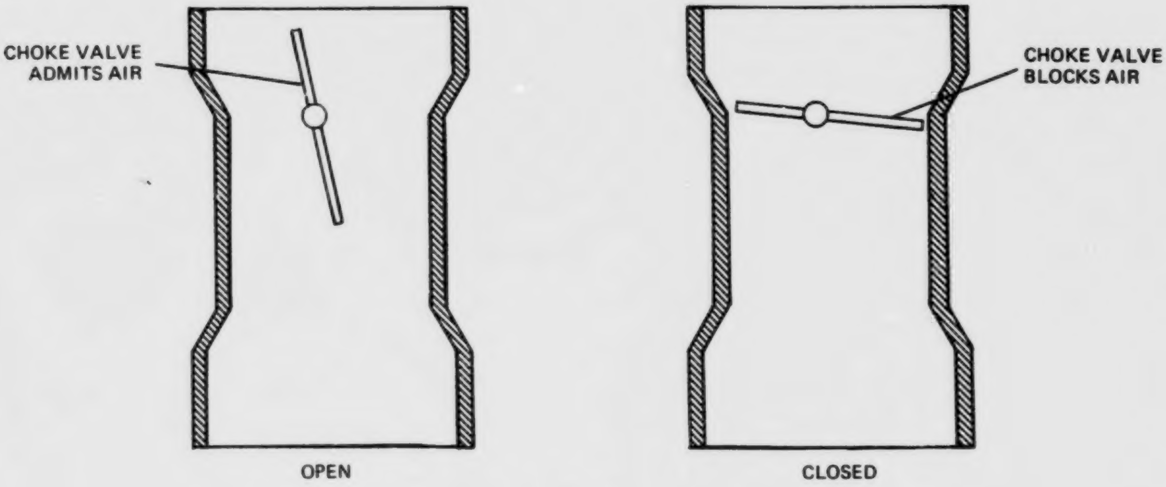


Figure 4-37. Choke Valve Operation.

(1) *Electricity (Fig. 4-40).* A large portion of the vehicles currently produced use an electric coil to heat the thermostatic coil. The heating coil is switched on with the ignition switch. Some systems employ a control unit that prevents power from reaching the electric coil until the engine compartment reaches a desired temperature.

(2) *Engine Coolant (Fig. 4-41).* Another method of heating the thermostatic coil is to circulate engine coolant through a passage in the thermostat housing.

(3) *Intake Manifold Crossover (Fig. 4-42).* One of the most popular methods of providing choke heat, until recent years, is to utilize exhaust heat. The most popular way of doing this is to mount the choke mechanism containing the thermostatic coil in a molded well on the intake manifold over the crossover passage. The choke mechanism then operates the choke valve through linkage.

(4) *Exhaust Manifold (Fig. 4-43).* This system has the choke mechanism mounted on the carburetor in a sealed housing. The choke housing is connected to a tube that runs through

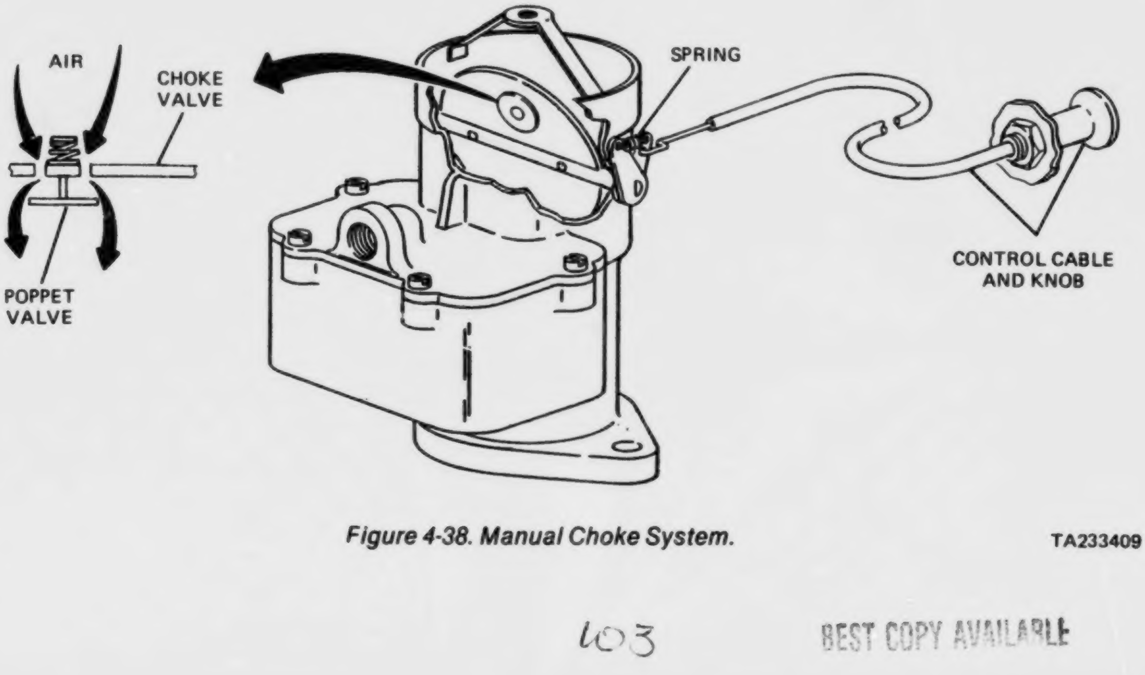


Figure 4-38. Manual Choke System.

TA233409

103

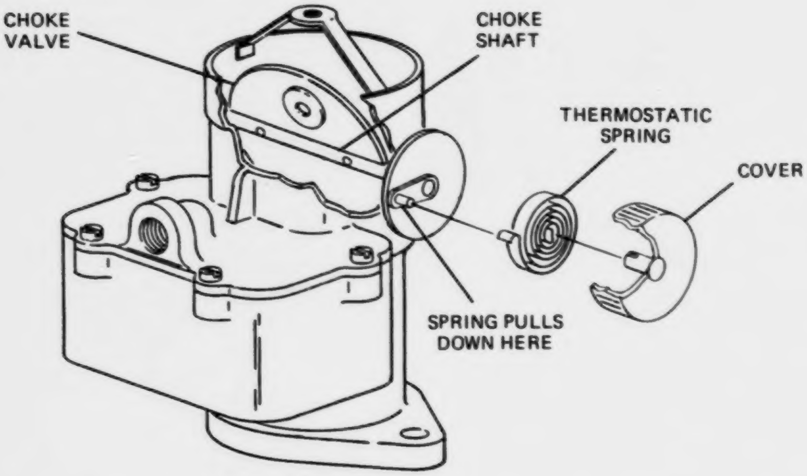


Figure 4-39. Automatic Choke System.

the exhaust manifold. This tube is to supply heat to the choke mechanism. The choke housing also is connected internally to a manifold vacuum source. As the engine runs, manifold vacuum draws air through the heat tube and the choke housing. The heat tube passes right through the exhaust manifold so that as it takes in fresh air via the choke stove, it will pick up heat from the exhaust without sending any actual exhaust fumes to the choke mechanism. Actual heating of the fresh air entering the heat tube occurs in the choke stove.

f. Regulating Choke Valve Opening. As with the manual choke system, a device must be incorporated that will open the choke a measured amount against the force of the thermostatic coil. Manifold vacuum usually is used to operate this device, which is usually in the two following configurations:

(1) *Choke Piston (Fig. 4-44).* The choke piston is integral with the carburetor, as is the passage that supplies vacuum to it. The vacuum passage is situated on the side of the piston cylinder so that it will only pull the choke valve open the desired amount before the piston will cover the vacuum passage. This will block the passage, keeping the piston from moving any further.

(2) *Choke Piston Integral with Choke Housing.* The choke piston system also may be

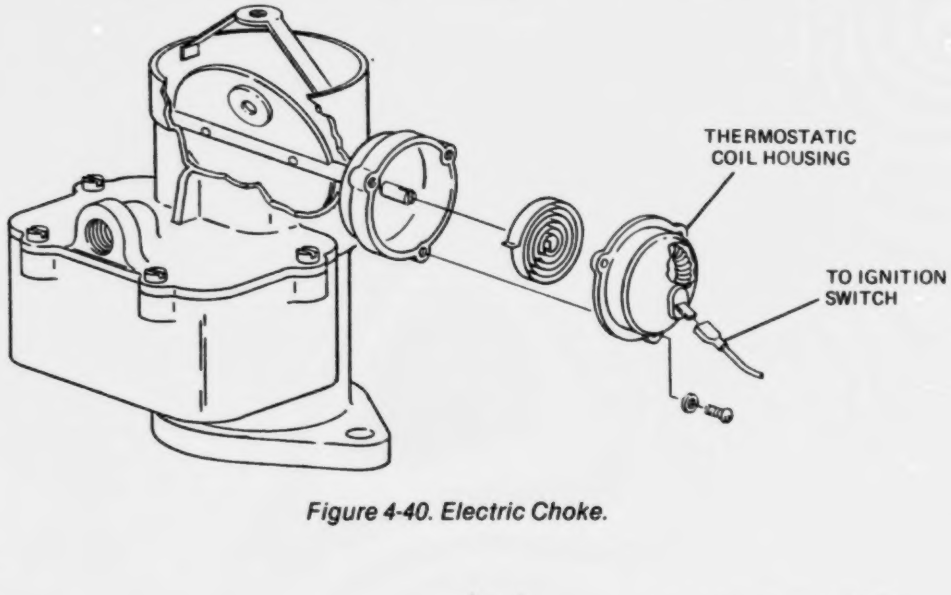


Figure 4-40. Electric Choke.

TA233410

104

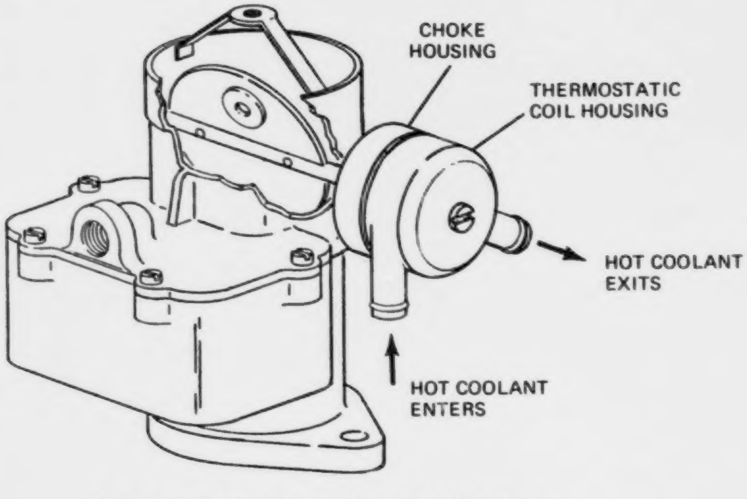

CHOKE
HOUSING
THERMOSTATIC
COIL HOUSING
HOT COOLANT
EXITS
HOT COOLANT
ENTERS

Figure 4-41. Engine Coolant Heated Choke.

integrated with the choke heating system as shown in figure 4-45. This is done by putting the choke piston into the choke housing. As manifold vacuum pulls the piston open, controlled leakage around the piston allows the same vacuum source to pull in heated air for the choke.

(3) *Remote Choke Pulloff (Fig. 4-46).* The remote choke pulloff is the most common configuration in current automotive design. It is made from either metal or plastic and uses a rubber diaphragm that pulls the choke open through linkage. The linkage is adjustable to obtain the proper choke valve opening. The lever on the choke shaft is slotted so it will not interfere with full choke valve opening.

(4) *Two-Stage Choke Pulloff (Fig. 4-47).* A variation of the choke pulloff is the two-stage choke pulloff that has a spring-loaded telescoping pull rod. The choke valve, in the beginning, will be pulled open only partially. As the thermostatic coil heats and relaxes, it will be overcome by the pressure of the spring on the telescoping pull

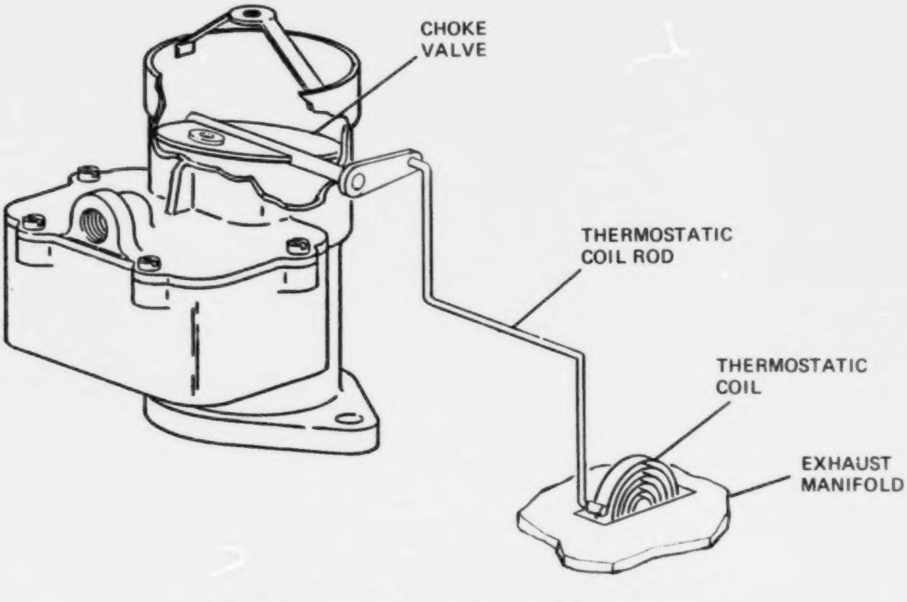

CHOKE
VALVE
THERMOSTATIC
COIL ROD
THERMOSTATIC
COIL
EXHAUST
MANIFOLD

Figure 4-42. Well-Type Exhaust Heated Choke.

TA233411

105

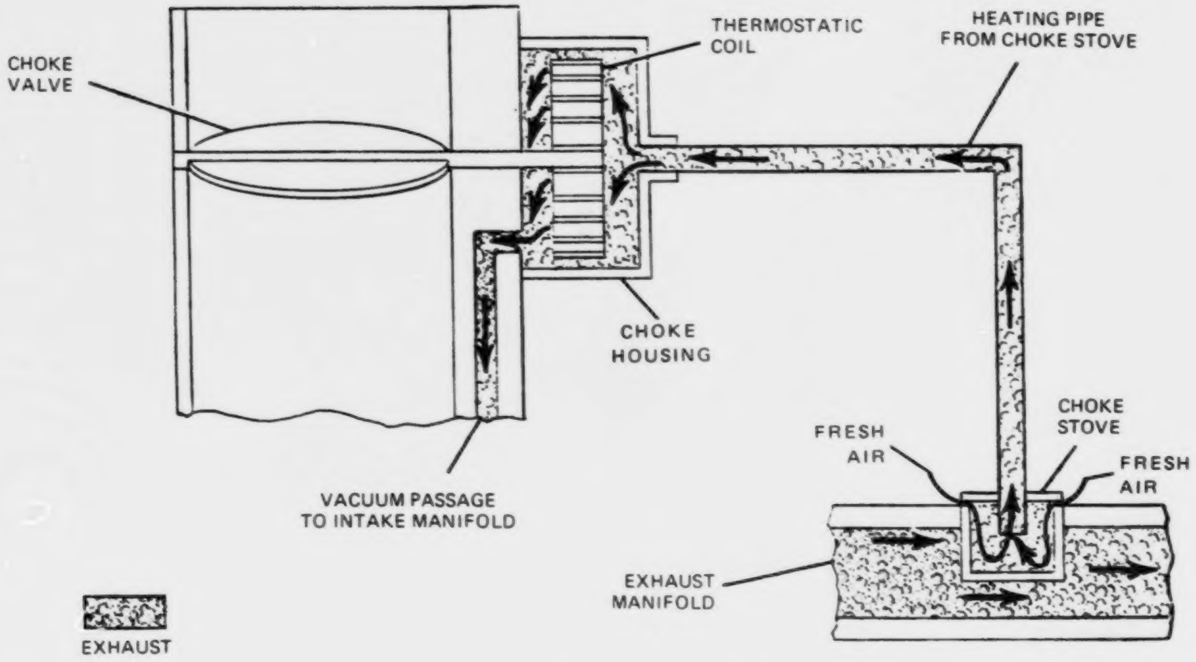

CHOKE VALVE
THERMOSTATIC COIL
HEATING PIPE FROM CHOKE STOVE
CHOKE HOUSING
VACUUM PASSAGE TO INTAKE MANIFOLD
CHOKE STOVE
FRESH AIR
FRESH AIR
EXHAUST MANIFOLD
EXHAUST

Figure 4-43. Exhaust Heat-Tube Type Choke.

rod and the choke valve will open further. This design provides more precise control and is popular with emission-controlled vehicles.

g. *Fast Idle Cam (Fig. 4-48).* When the choke system is operating during warmup, the engine must run at a faster idle speed to improve drivability and prevent flooding. To accomplish

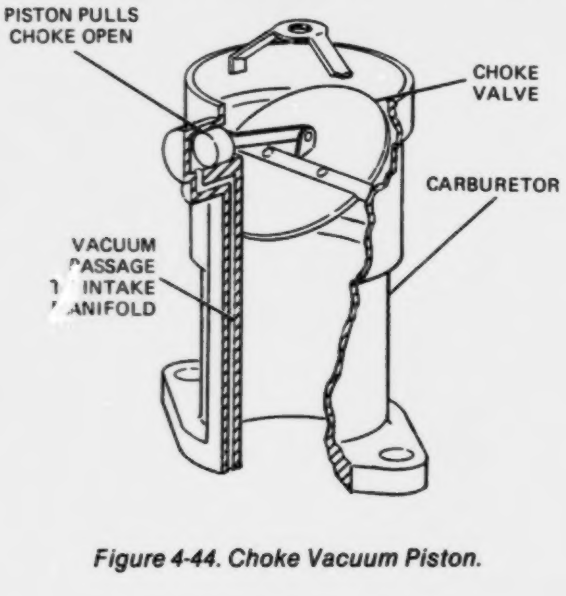

PISTON PULLS CHOKE OPEN
CHOKE VALVE
CARBURETOR
VACUUM
PASSAGE
T INTAKE
ANIFOLD

Figure 4-44. Choke Vacuum Piston.

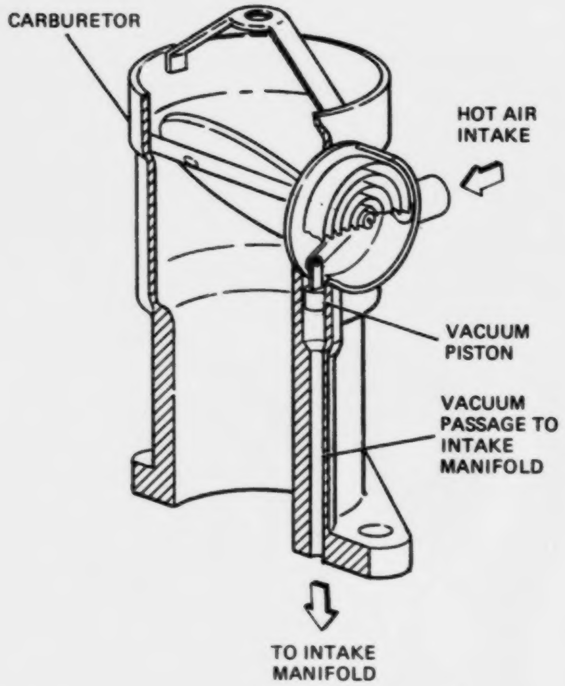

CARBURETOR
HOT AIR INTAKE
VACUUM PISTON
VACUUM PASSAGE TO INTAKE MANIFOLD
TO INTAKE MANIFOLD

Figure 4-45. Choke Piston Integral with Choke Housing.

TA233412

106

BEST COPY AVAILABLE

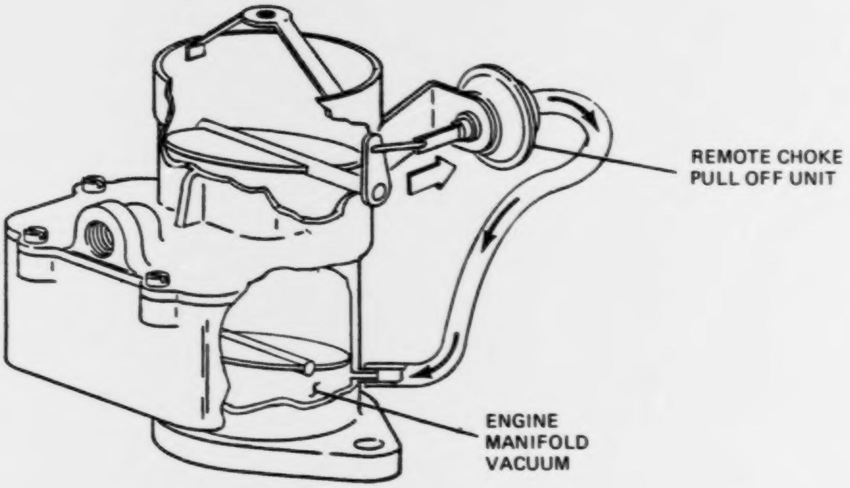


Figure 4-46. Remote Choke Pulloff.

this, the carburetor is fitted with a fast idle cam that is operated by linkage from the choke. The fast idle cam operates by holding the throttle valve open. As the choke valve gradually opens, the cam rotates, gradually reducing idle speed.

h. Choke Unloader (Fig. 4-49). If for some reason the engine should flood when it is cold, a device is needed to open the choke so that air may be admitted to correct the condition. The device that accomplishes this is the choke unloader. The choke unloader usually consists of a projection from the fast idle cam that interacts with the throttle linkage. The operation is as follows:

(1) As the throttle valve is fully opened, the projection on the throttle lever contacts the projection on the fast idle cam.

(2) The throttle lever, through the fast idle cam, then pulls the choke valve open a measured amount.

4-20. Multiple-Venturi Carburetion.

a. General. A multiple-venturi or multiple-barrel carburetor is really a carburetor that has two or four separate single-venturi carburetors arranged in a cluster that in most cases share a

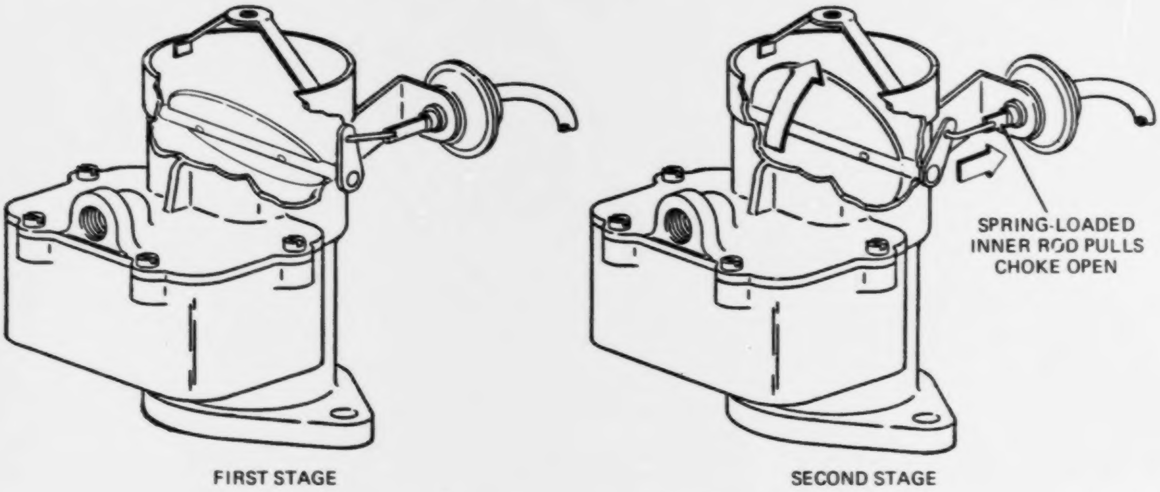
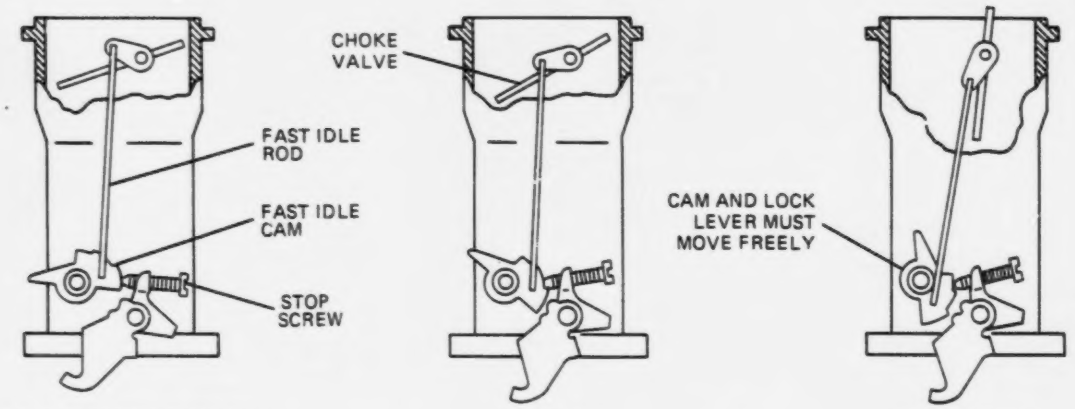


Figure 4-47. Two-Stage Choke Pulloff.

TA233413

107



COLD STARTING POSITION

WARMUP

HOT POSITION

Figure 4-48. Fast Idle Cam Operation.

common choke, float, and accelerator pump system.

b. Purpose. There are two reasons for using multiple-venturi carburetion:

(1) The use of two separate carburetors, each feeding separate cylinders, can help to improve fuel distribution.

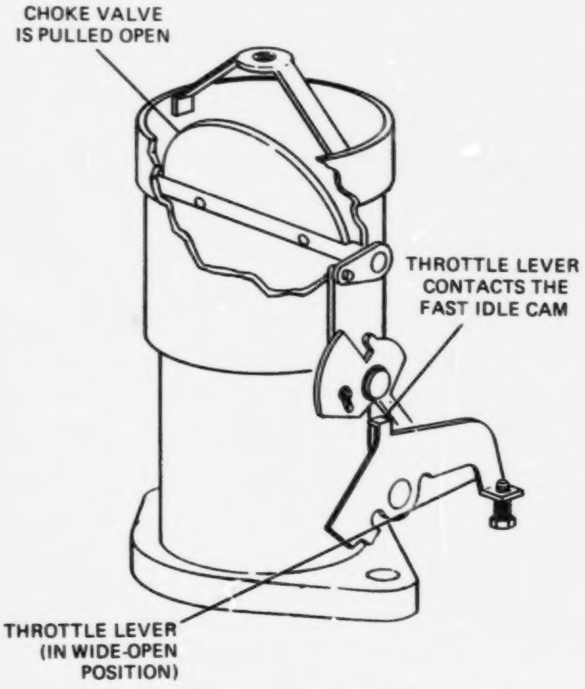

CHOKE VALVE IS PULLED OPEN
THROTTLE LEVER CONTACTS THE FAST IDLE CAM
THROTTLE LEVER (IN WIDE-OPEN POSITION)

Figure 4-49. Choke Unloader.

(2) The operating range of the engine can be increased and drivability improved if the throttle linkage is arranged to phase in the carburetor venturis gradually as the accelerator pedal is depressed.

There are two basic arrangements for the throttle linkage, depending on the purpose for having multiple-venturi carburetion. The linkage arrangements are discussed in the next two subparagraphs.

c. Fixed Throttle Linkage (Fig. 4-50). Fixed throttle linkage is used mostly on two-venturi or two-barrel carburetors on engines containing six or more cylinders. This linkage arrangement usually is installed on an intake manifold that is arranged so that each venturi is feeding a selected half of the cylinders. The separation of the carburetor venturis within the intake manifold usually is to keep consecutively operating cylinders separated. Whenever two cylinders go through power strokes consecutively, the second of the two cylinders tends to have its fuel supply cut off. The fixed throttle linkage arrangement is a solid throttle shaft that operates both throttle valves simultaneously. There is an idle mixture screw on each side of the carburetor. The accelerator pump discharge nozzle usually contains two outlets.

d. Progressive Throttle Linkage. Progressive throttle linkage is set up to open one throttle valve or one set of throttle valves at the beginning of the linkage travel and begin to open the second

TA233414

108

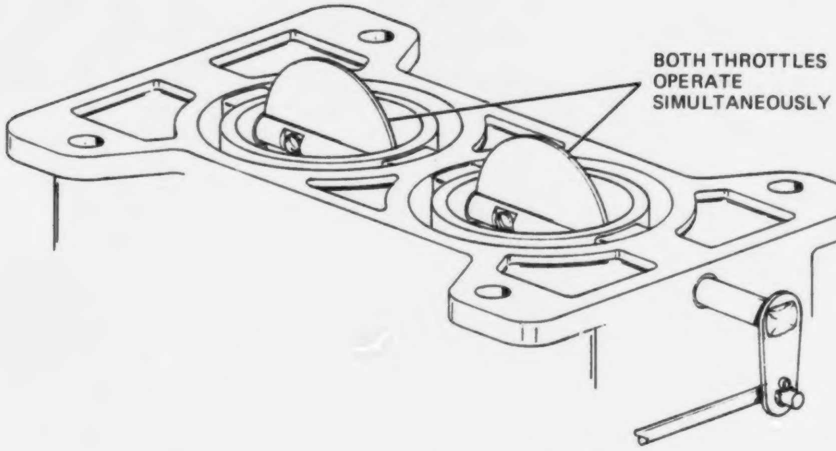


Figure 4-50. Two-Barrel Carburetor with Fixed Linkage.

throttle valve or set of throttle valves when the first is about two-thirds open. The geometry of the linkage is set up so that as the throttle reaches the full open point, all of the throttle valves will be wide open. The purpose is to provide a carburetor that will have a venturi that is small enough to provide good throttle response and fuel economy at low speed, yet be large enough to allow the engine to perform well at high speed. The section of the carburetor that operates at low speed is called the primary section while the section that operates at high speed is called the secondary section. It should be noted that the primary section of the carburetor works throughout the engine's operational range. It should also be noted that the secondary section of the carburetor has no choke, accelerator pump, low-speed, idle, or high-speed enrichment system. These systems are unnecessary in the secondary section of the carburetor for the following reasons:

(1) The secondary section of the carburetor is locked out so that its throttle valve(s) will not open when the choke system is operational on the primary side of the carburetor.

(2) At the speed that the engine is operating when the secondary section of the carburetor begins to operate, there will be no hesitation without an acceleration pump system.

(3) Because the secondary section of the carburetor only operates at high speeds, it does not have to be jetted for two stages of operation and therefore will not require a high-speed enrichment system.

(4) Because the secondary section of the carburetor operates only at high speeds, a low-speed and idle system are unnecessary.

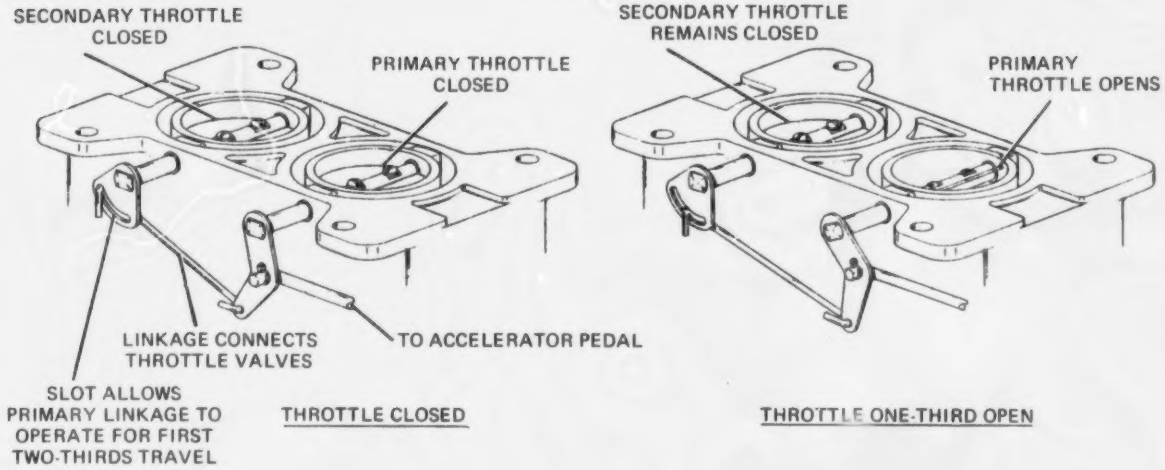
There are numerous devices and systems of linkage that are used to make the secondary section of the carburetor operate. They will be discussed in the following subparagraphs.

e. Progressive Linkage Configurations. A carburetor equipped with progressive linkage is designed so that the accelerator pedal directly operates the primary throttle valve(s). There are two ways in which the secondary throttle valve(s) are operated.

(1) Mechanically operated secondary throttle valve(s) (fig. 4-51) are actuated by linkage from the primary throttle valve(s). The linkage is designed so that it will not be actuated until the primary throttle valve(s) are approximately two-thirds open. The operating arm on the primary throttle shaft is made to be approximately three times as long as the arm on the secondary throttle shaft so that the secondary throttle valve(s) will open all the way during the final third of primary throttle valve opening. The operating arm on the secondary throttle shaft operates through a spring so that it will not interfere with the primary throttle operation when the choke lockout is engaged.

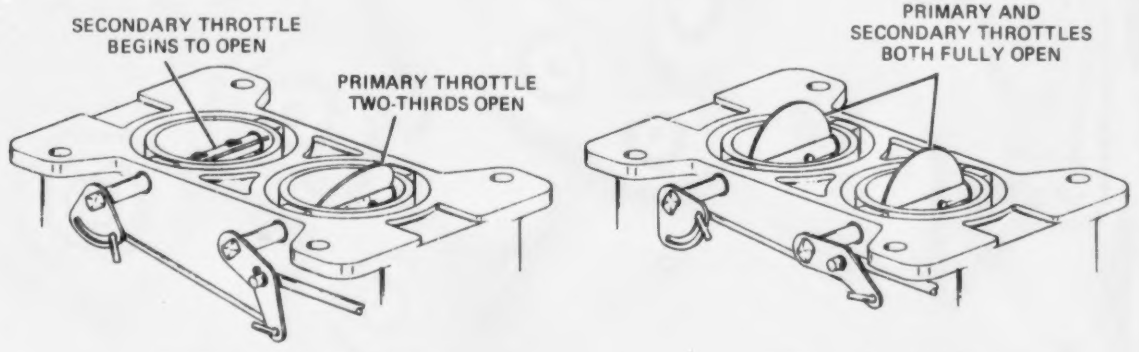
(2) Vacuum-operated secondary throttle valve(s) (fig. 4-52) are actuated by a vacuum

TA233415


SECONDARY THROTTLE CLOSED
PRIMARY THROTTLE CLOSED
LINKAGE CONNECTS THROTTLE VALVES
TO ACCELERATOR PEDAL
SLOT ALLOWS PRIMARY LINKAGE TO OPERATE FOR FIRST TWO-THIRDS TRAVEL
SECONDARY THROTTLE REMAINS CLOSED
PRIMARY THROTTLE OPENS

THROTTLE CLOSED

THROTTLE ONE-THIRD OPEN


SECONDARY THROTTLE BEGINS TO OPEN
PRIMARY THROTTLE TWO-THIRDS OPEN
PRIMARY AND SECONDARY THROTTLES BOTH FULLY OPEN

THROTTLE TWO-THIRDS OPEN

THROTTLE FULLY OPEN

Figure 4-51. Mechanical Progressive Linkage Operation.

diaphragm whose vacuum source is the primary venturi. The principle of operation is that as engine speed increases, the vacuum in the primary venturi also increases, causing the diaphragm to pull the secondary throttle valves open. There is linkage between the primary and secondary throttle shafts to limit the opening of the secondary throttle valve(s) in relation to the primary throttle valves.

f. Secondary Air Valve (Fig. 4-53). Carburetors equipped with mechanically operated secondary throttle valves are subject to engine hesitation if the throttle suddenly is opened all the way at low engine speeds for the following reasons:

(1) The opening of primary and secondary throttle valves provides too much venturi area for the engine to handle at low speed. It will not be able to move enough air through the venturis to properly draw fuel from the discharge tubes, causing a lean mixture.

(2) The secondary section of the carburetor is not equipped with an accelerator pump system and will cause an engine hesitation at low speed. To correct this deficiency, most carburetors with mechanical progressive linkage use a secondary air valve. A secondary air valve fits into the secondary throat and serves to restrict airflow through the secondary venturi(s) until the engine is at a high enough speed to utilize them correctly. The valve is actuated by a vacuum under it that pulls it open against spring or counterweight force.

TA233416

110

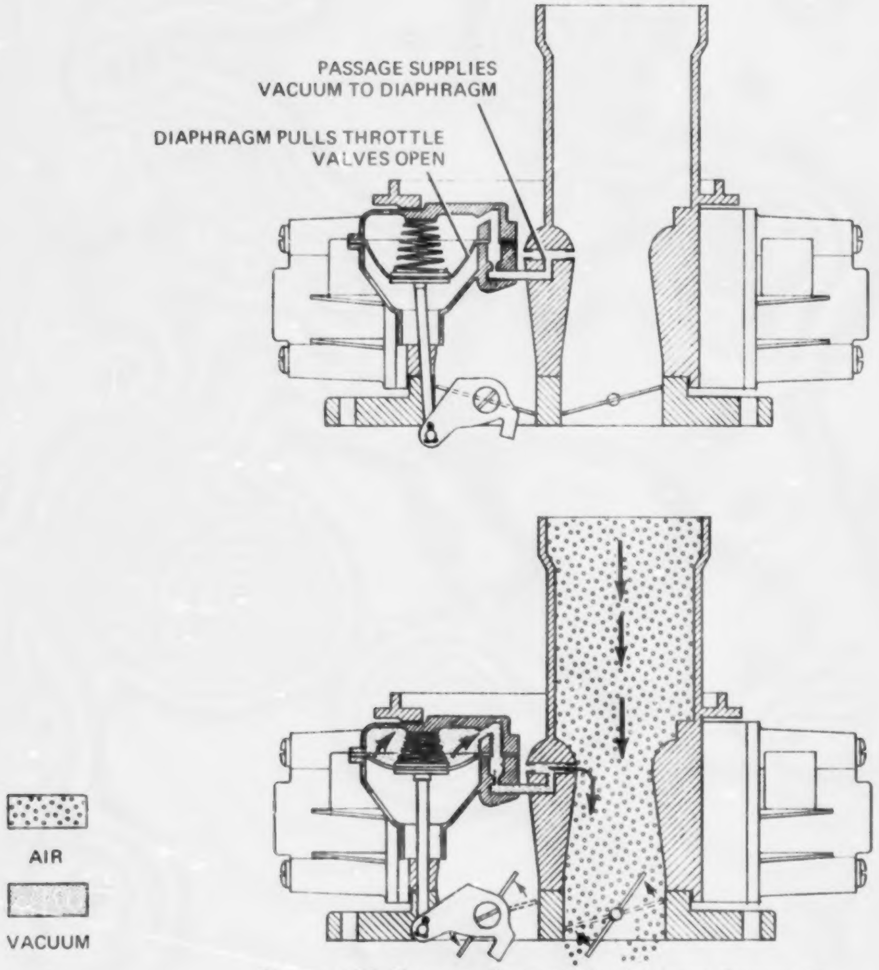

PASSAGE SUPPLIES VACUUM TO DIAPHRAGM
DIAPHRAGM PULLS THROTTLE VALVES OPEN
AIR
VACUUM

Figure 4-52. Vacuum Progressive Linkage Operation.

g. Four-Barrel Carburetor (Fig. 4-54). The four-barrel or four-venturi carburetor consists of two primary venturis on a fixed throttle shaft that are progressively linked to two secondary venturis that are also on a fixed throttle shaft. The four-barrel carburetor is popular for the V-8 engine configurations for the following reasons:

(1) The intake manifold may be divided to separate consecutive cylinders (para 4-20c).

(2) The carburetor better serves the engine throughout the entire load and speed range.

4-21. Updraft, Downdraft, and Sidedraft Carburetion. Carburetors may be built so that the airflow in the throat is downward, upward, or sideways, as shown in figure 4-55.

4-22. Primer System (Fig. 4-56). Some gasoline engines are fitted with a primer system to aid cold starting. The primer system consists of a hand pump that forces gasoline through a line to inject it at strategic locations along the intake manifold. The system is not used very much in modern equipment.

4-23. Degasser System (Fig. 4-57). The degasser system is designed to shut off the supply of fuel to the idle circuit whenever there is high manifold vacuum such as periods of deceleration preventing large amounts of fuel from being drawn into the engine through the idle port. The degasser consists of a needle valve, a spring that

TA233417

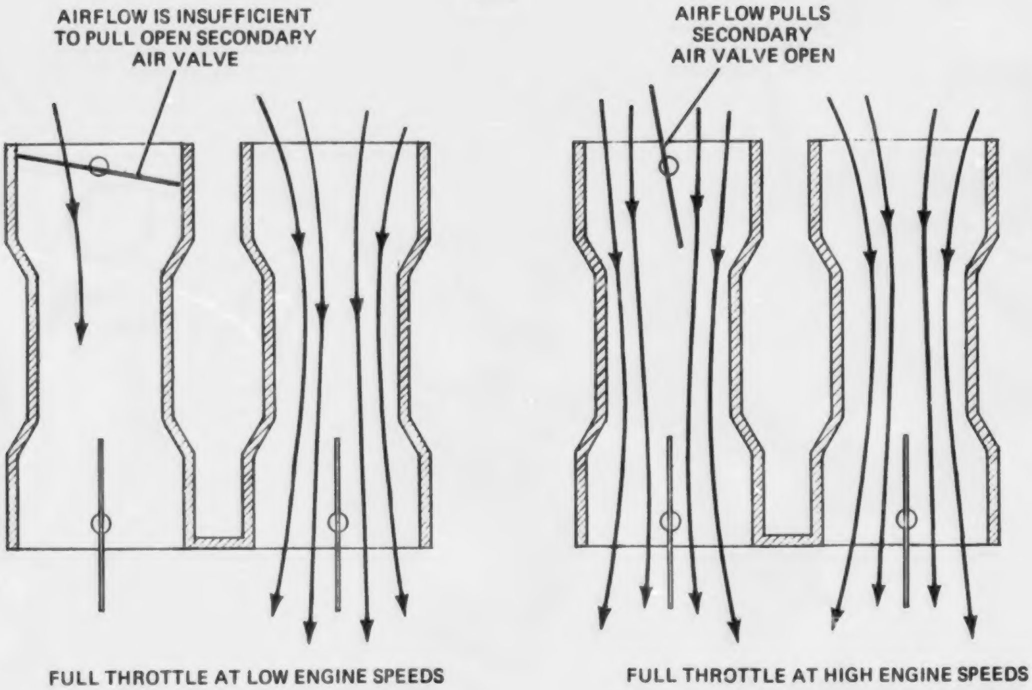

AIRFLOW IS INSUFFICIENT TO PULL OPEN SECONDARY AIR VALVE
AIRFLOW PULLS SECONDARY AIR VALVE OPEN
FULL THROTTLE AT LOW ENGINE SPEEDS
FULL THROTTLE AT HIGH ENGINE SPEEDS

Figure 4-53. Secondary Air Valve Operation.

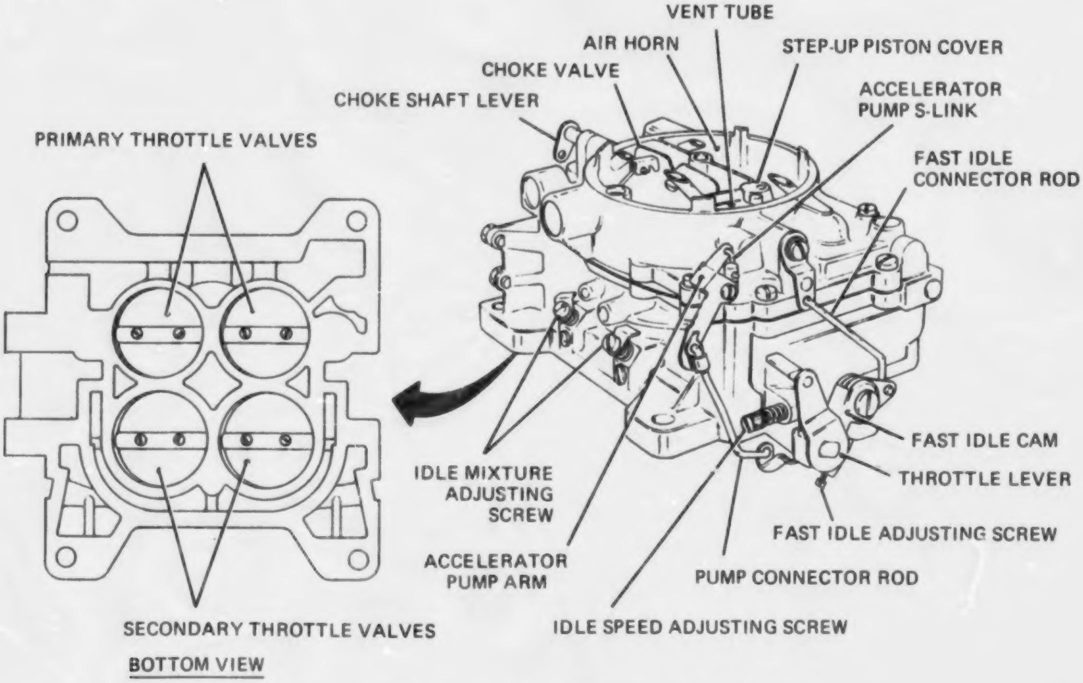

VENT TUBE
AIR HORN
STEP-UP PISTON COVER
CHOKE VALVE
CHOKE SHAFT LEVER
ACCELERATOR PUMP S-LINK
PRIMARY THROTTLE VALVES
FAST IDLE CONNECTOR ROD
FAST IDLE CAM
THROTTLE LEVER
IDLE MIXTURE ADJUSTING SCREW
FAST IDLE ADJUSTING SCREW
ACCELERATOR PUMP ARM
PUMP CONNECTOR ROD
SECONDARY THROTTLE VALVES
IDLE SPEED ADJUSTING SCREW
BOTTOM VIEW

Figure 4-54. Typical Four-Barrel Carburetor.

TA233418

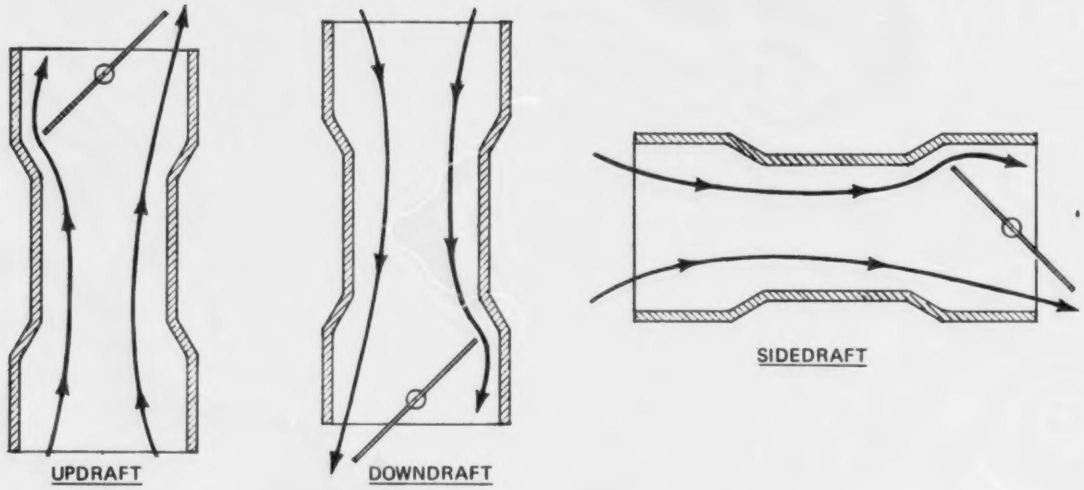

UPDRAFT
DOWNDRAFT
SIDEDRAFT

Figure 4-55. Updraft, Downdraft, and Sidedraft Carburetors.

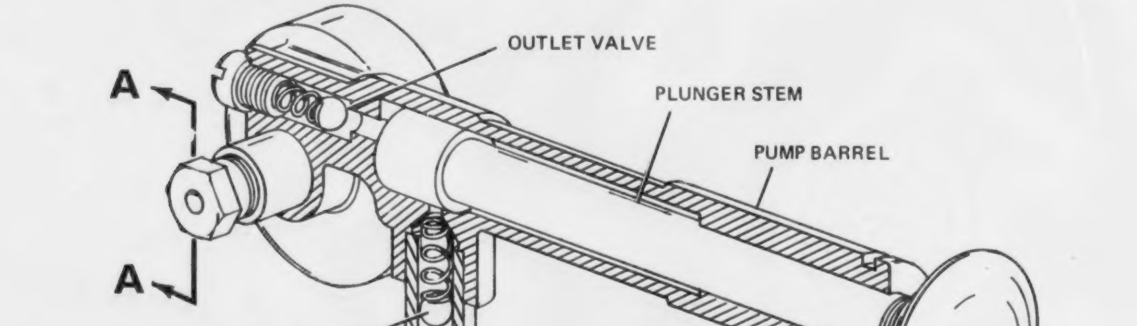
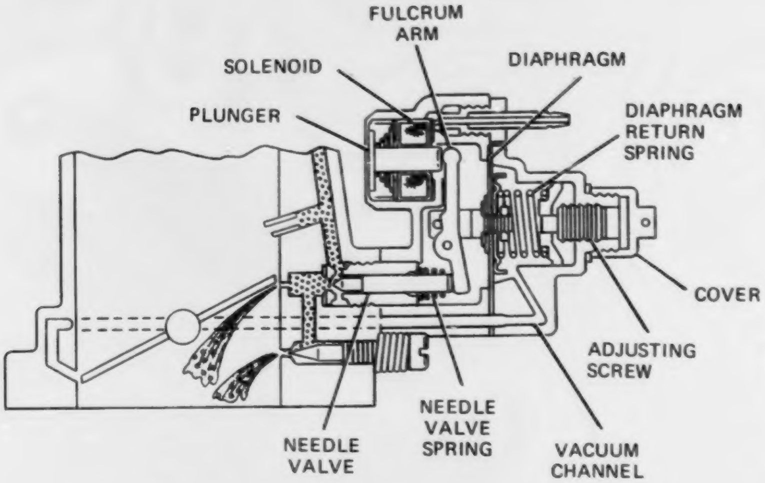
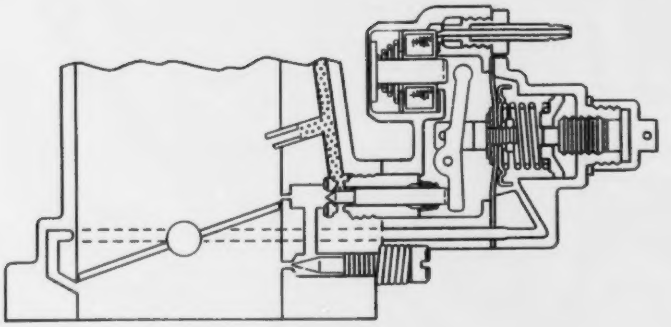

A
A
OUTLET VALVE
PLUNGER STEM
PUMP BARREL
INLET VALVE
CUTAWAY OF COMPLETE PUMP
DIAPHRAGM
SECTION A-A
THROUGH DIAPHRAGM SECTION
FROM FUEL TANK

Figure 4-56. Primer System.

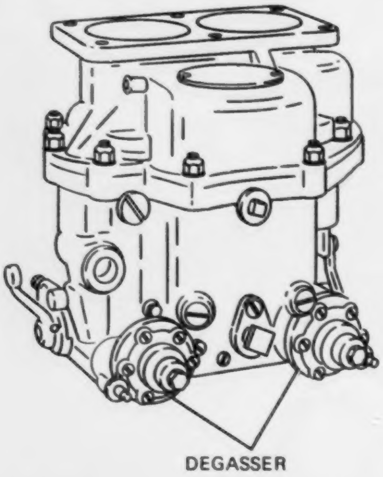
TA233419

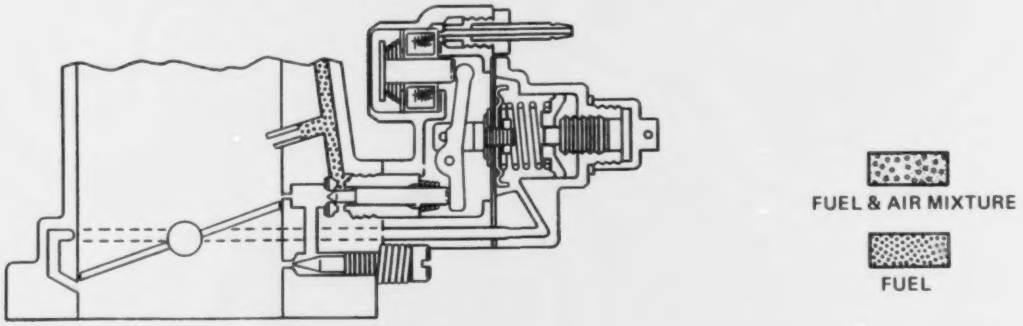

FULCRUM ARM
SOLENOID
DIAPHRAGM
PLUNGER
DIAPHRAGM RETURN SPRING
COVER
ADJUSTING SCREW
NEEDLE VALVE SPRING
VACUUM CHANNEL
NEEDLE VALVE

DEGASSER WITH IDLE SYSTEM OPERATING



DEGASSER WITH ENGINE DECELERATING




FUEL & AIR MIXTURE
FUEL

DEGASSER WITH ELECTRIC SHUTOFF OPERATING

Figure 4-57. Degasser System.

TA233420

holds the needle valve open, and a vacuum diaphragm that operates the needle valve through a fulcrum. The diaphragm is operated by a manifold vacuum. During periods of normal engine idle, the manifold vacuum is not high enough to operate the diaphragm and the needle valve remains open. During periods of deceleration, the manifold vacuum is high enough to cause the diaphragm to close the needle valve, shutting off the idle system. The needle valve also can be closed by pushing a button on the instrument panel that will energize a solenoid, closing the needle valve. The purpose of this manual actuation device is to clear the idle circuit and manifold of unburned gases before the engine is turned off.

4-24. Accessory Systems. There are numerous devices that are used on carburetors to improve drivability and economy. Their application varies from vehicle to vehicle. The following subparagraphs list the most popular of these devices.

a. *Hot Idle Compensator (Fig. 4-58).* The hot idle compensator is a thermostatically controlled valve that helps to prevent engine stalling when idling in very hot weather. Long periods of engine idle cause an excessive amount of vaporization of gasoline in the float bowl. These vapors will find their way into the carburetor throat and cause an overly rich mixture. The hot idle compensator consists of a bimetallic strip of metal operating a valve that controls an air passage that ends under the throttle valve. The bimetallic strip, which consists of two pieces of dissimilar metal with different expansion rates, will curl upwards as the temperature increases, opening the valve. This will in turn admit air under the throttle valve compensating for the overly rich mixture.

b. *Throttle Return Dashpot (Fig. 4-59).* The throttle return dashpot acts as a damper to keep the throttle from closing too quickly when the accelerator pedal is suddenly released. This is important to prevent stalling on cars equipped with automatic transmissions. The throttle lever contacts the dashpot rod just before the throttle valves close. This will, in turn, push in on the diaphragm. The diaphragm slows the closing of the throttle because it must exhaust the air from the chamber through a tiny venthole. When the throttle opens again, the dashpot spring pushes the diaphragm back into operating position, drawing air into the chamber.

c. *Antidiesel Solenoid (Fig. 4-60).* The antidiesel solenoid controls the throttle opening at engine idle to prevent dieseling. Engine dieseling is a condition that causes the engine to continue running after the ignition switch is turned off. It is a particular problem with newer emission controlled vehicles due to higher operating temperatures, higher idle speeds, leaner fuel mixtures, and lower octane gasoline (para 4-40). The solenoid is energized when the ignition switch is turned on, causing the plunger to open the throttle to idle speed position. The plunger length is adjustable so that the idle speed can be adjusted. When the ignition switch is turned off, the solenoid is deenergized and the throttle closes tightly, cutting off the air-fuel mixture. This will keep the engine from dieseling.

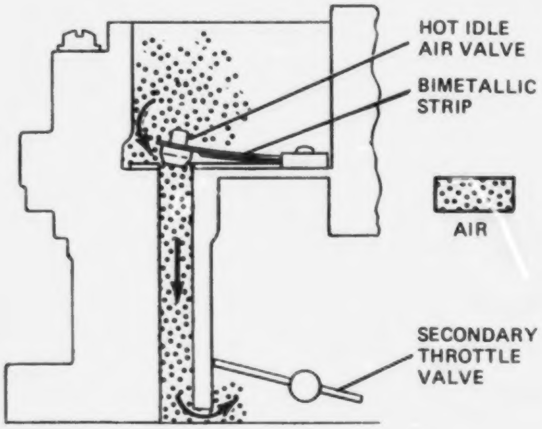


Figure 4-58. Hot Idle Compensator.

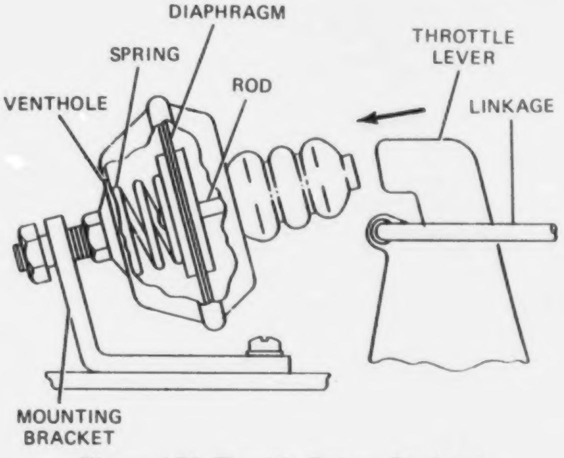


Figure 4-59. Throttle Return Dashpot.

TA233421

115

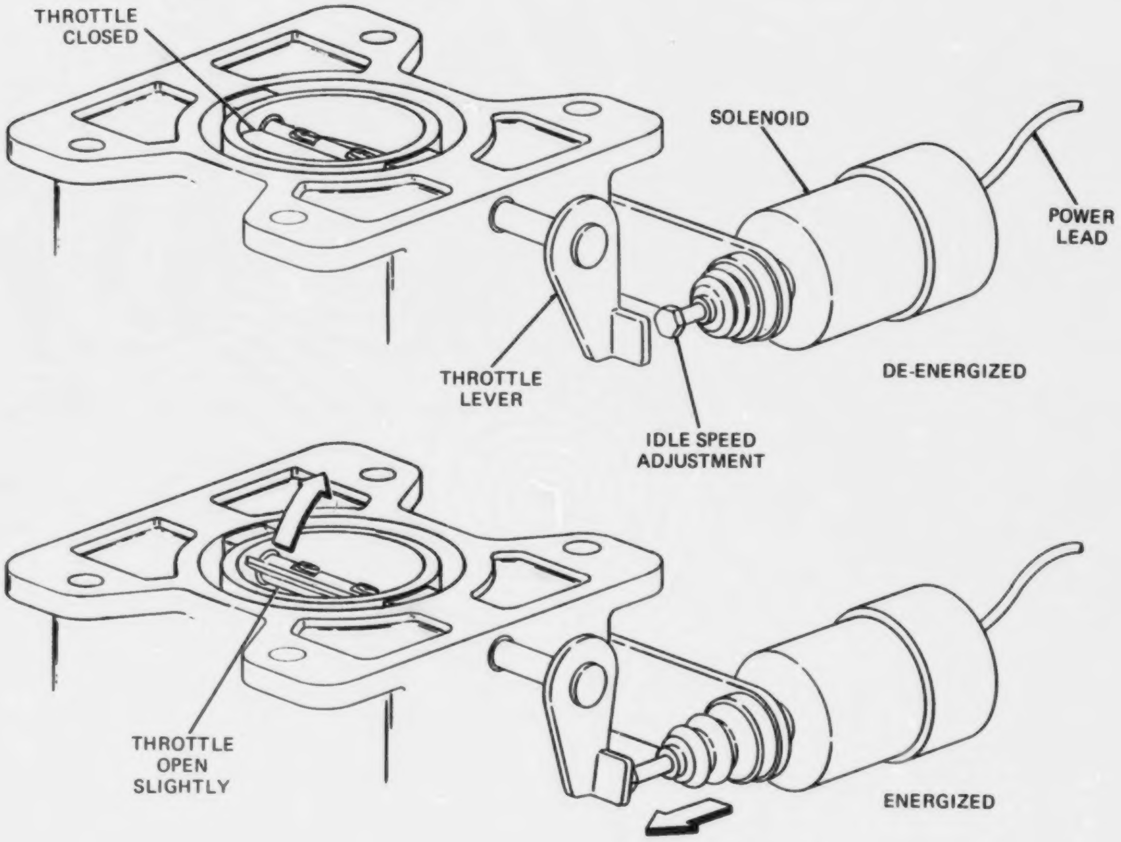


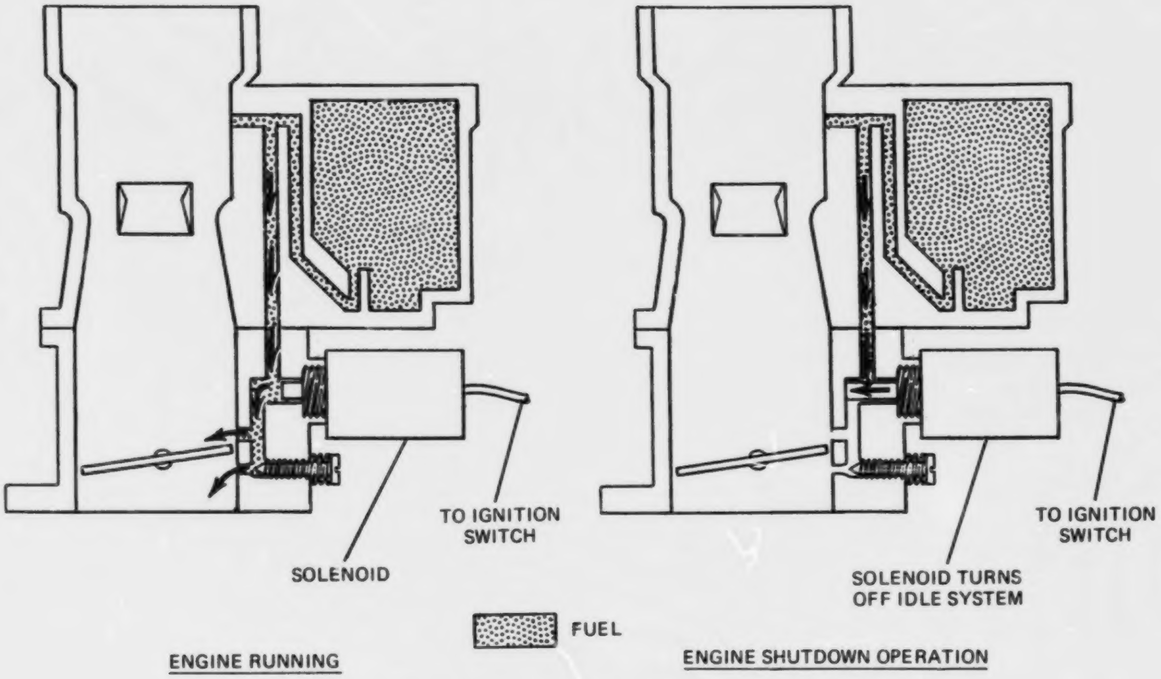
Figure 4-60. Antidiesel/Air-Conditioning Solenoid Operation.

d. Air-Conditioning Solenoid (Fig. 4-60). The air-conditioning solenoid is used on some engines to boost engine idle speed whenever the air-conditioner compressor is running. This compensates for the load placed on the engine, thus preventing stalling. Its operation is similar to the antidiesel solenoid described in the preceding subparagraph.

e. Idle Solenoid System (Fig. 4-61). The idle solenoid system serves the same purposes as the degasser system described in paragraph 4-23. The system uses a solenoid whose operation is similar to the ones used in the two preceding subparagraphs. The solenoid operates a needle valve that opens and closes the carburetor idle port. The needle valve is in a normally closed position. The solenoid is activated when the ignition switch is turned on, opening the needle valve. The purpose of shutting off the idle system with the engine is to help eliminate engine dieseling (para 4-40). A sensing switch is located in the intake manifold to shut off the idle system whenever manifold vacuum is excessively high, to prevent excess amounts of fuel from being sucked in through the idle port during deceleration.

f. Heated Air Intake System (Fig. 4-62). Most later model vehicles are fitted with a heated air intake system to provide the best performance in all temperatures with leaner fuel mixtures. The heated air intake system uses a damper door in the air filter snorkel to select either cold fresh air intake or heated air that is ducted from a heat stove on the exhaust manifold. The damper door is moved by a diaphragm that operates by manifold vacuum. The position of the damper door is determined by a temperature sensor. The system will keep the temperature of the intake air at about 100° to 115°F (37.8° to 46.1°C). Operation is as follows:

TA233422



ENGINE RUNNING

ENGINE SHUTDOWN OPERATION

Figure 4-61. Idle Solenoid System Operation.

(1) When inlet air temperature is below 100°F (37.8°C), the temperature sensor will allow full vacuum to flow to the operating diaphragm, pulling the damper door to the heated air position.

(2) When the inlet air is over 115°F (46.1°C), the temperature sensor will bleed manifold vacuum off into the atmosphere. This will cause the diaphragm spring to push the damper door into the unheated fresh air position.

(3) The temperature sensor will at times also bleed off only a portion of vacuum, causing the damper door to remain between the hot and cold position. This will regulate the temperature by providing a blend of hot and cold air.

(4) At any time the engine is heavily accelerated, the manifold vacuum will drop and the damper door will move to the fresh air intake position.

TA233423

117

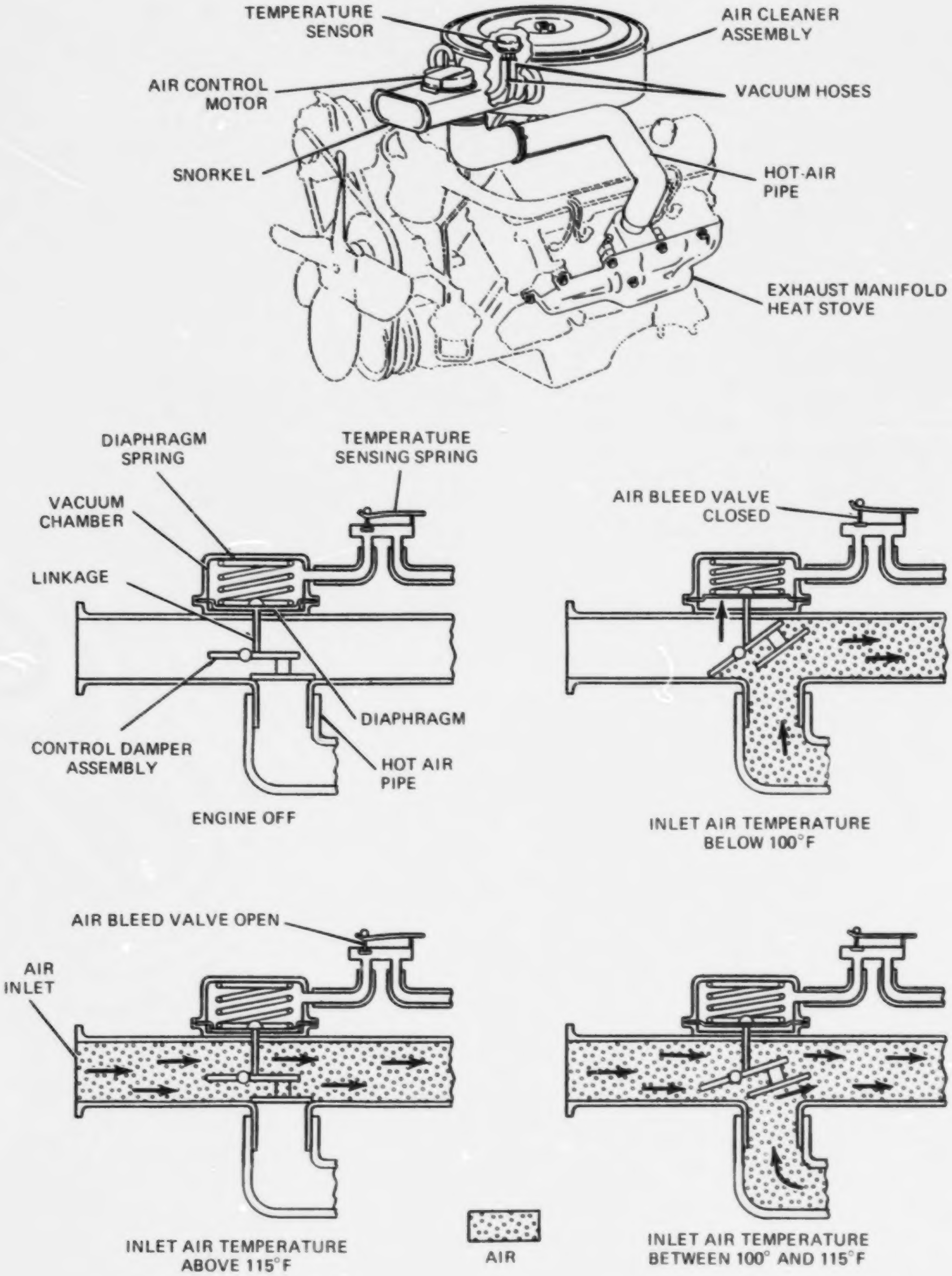

TEMPERATURE SENSOR
AIR CLEANER ASSEMBLY
AIR CONTROL MOTOR
VACUUM HOSES
SNORKEL
HOT-AIR PIPE
EXHAUST MANIFOLD HEAT STOVE
DIAPHRAGM SPRING
TEMPERATURE SENSING SPRING
VACUUM CHAMBER
LINKAGE
DIAPHRAGM
CONTROL DAMPER ASSEMBLY
HOT AIR PIPE
ENGINE OFF
AIR BLEED VALVE CLOSED
INLET AIR TEMPERATURE BELOW 100°F
AIR BLEED VALVE OPEN
AIR INLET
INLET AIR TEMPERATURE ABOVE 115°F
AIR
INLET AIR TEMPERATURE BETWEEN 100° AND 115°F

Figure 4-62. Heated Air Intake System Operation.

TA233424

118

Section V. FUEL INJECTION SYSTEMS

FOR GASOLINE ENGINES

4-25. General. Fuel injection systems are an increasingly popular alternative to the carburetor for providing an air-fuel mixture. They inject, under pressure, a measured amount of fuel into the intake air, usually at a point near the intake valve. Fuel injection systems provide the following advantages.

(1) Fuel delivery can be measured with extreme accuracy, giving the potential for improved fuel economy and performance.

(2) Because the fuel is injected at the intake port of each cylinder, fuel distribution will be much better and fuel condensing in the manifold will not be a problem.

(3) There is no venturi to restrict the air intake, making it easier to keep volumetric efficiency high (para 2-23).

(4) The fuel injector, working under pressure, can atomize the fuel much finer than the carburetor, resulting in improved fuel vaporization.

There are three basic configurations of gasoline fuel injection: timed, continuous, and throttle body.

4-26. Timed Fuel Injection Systems.

a. General. Timed fuel injection systems for gasoline engines inject a measured amount of fuel in timed bursts that are synchronized to the intake strokes of the engine. Timed injection is the most precise form of fuel injection but it is also the most complex. There are two basic forms of timed fuel injection: mechanical and electronic. The operation of the two are very different and will be covered separately in the two following subparagraphs.

b. Mechanical-Timed Injection (Fig. 4-63). The mechanical-timed injection system uses a high-pressure pump that draws fuel from the gas tank and delivers it to the metering unit. A pressure relief valve is installed between the fuel pump and the metering unit to regulate fuel line pressure by bleeding off excess fuel back to the gas tank. The metering unit is a pump that is driven by the engine camshaft. It is always in the same rotational relationship with the camshaft so that it can be timed to feed the fuel at just the right moment to the injectors. There is one injector for each cylinder. Each injector contains a spring-loaded valve that is opened by fuel pressure injecting fuel into the intake at a point just before the intake valve. The throttle valve regulates engine speed and power output by regulating manifold vacuum, which in turn regulates the amount of fuel supplied to the injectors by the metering unit.

c. Electronic-Timed Fuel Injection (Fig. 4-64). The operation of electronic-timed fuel injection is somewhat different than the mechanical-timed system described in the previous subparagraph. In an electronic system, all of the fuel injectors are connected in parallel to a common fuel line that is fed by a high-pressure pump from the gas tank. A fuel pressure regulator also is installed in line with the injectors to keep fuel pressure constant by diverting excess fuel back to the gas tank. Each injector contains a solenoid valve and is normally in a closed position. With a pressurized supply of fuel behind it, each injector will operate individually whenever an electric current is applied to its solenoid valve. By sending electric current impulses to the injectors in a sequence timed to coincide with the needs of the engine, the system will supply gasoline to the engine as it should. The system is fitted with an electronic computer to serve this function and the function of providing the proper amount of fuel. The computer receives a signal from the ignition distributor to establish the timing sequence. The engine is fitted with a variety of sensors and switches that gather information such as:

(1) Intake air temperature

(2) Engine speed

(3) Manifold vacuum

(4) Engine coolant temperature

119

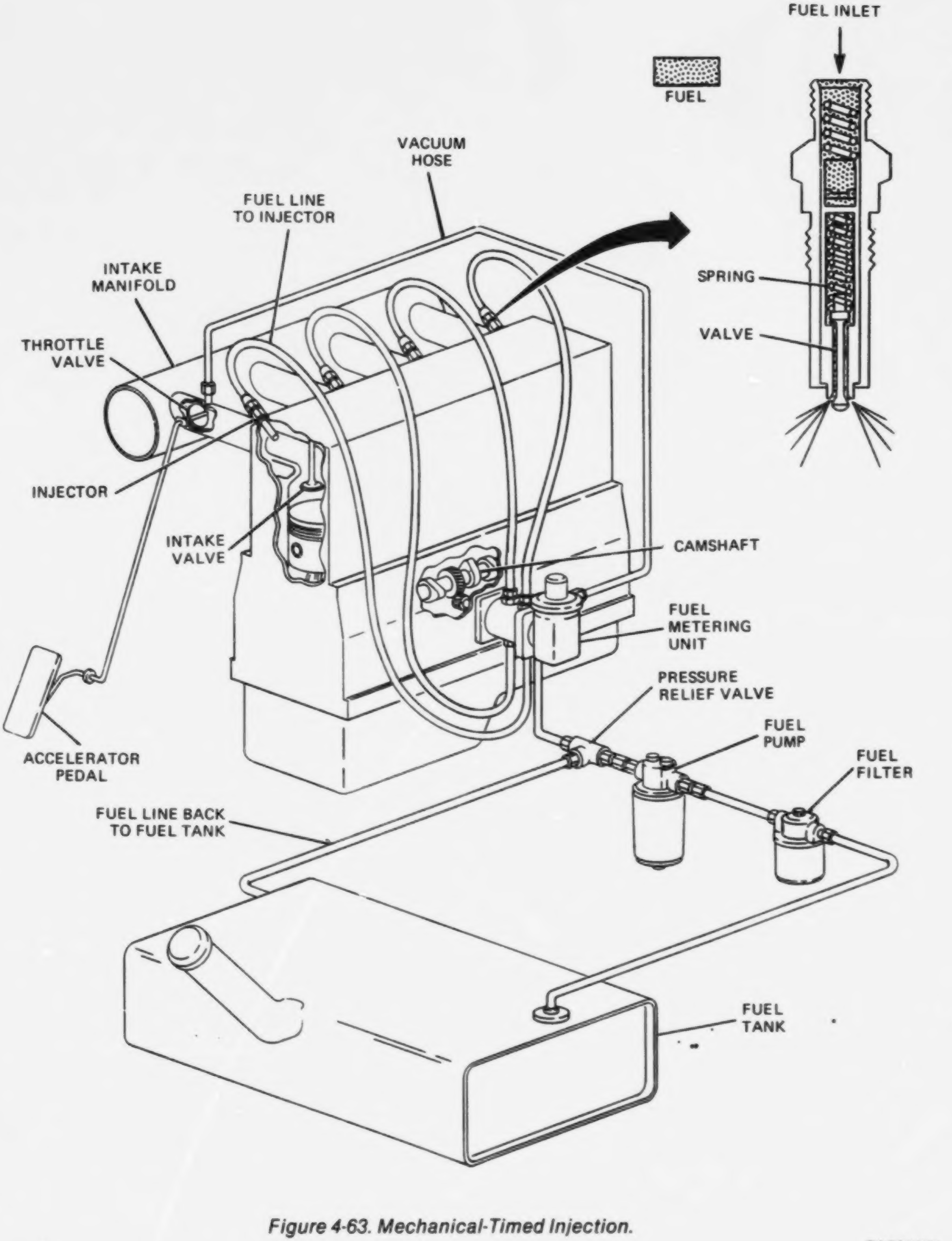

FUEL INLET
FUEL
VACUUM HOSE
FUEL LINE TO INJECTOR
INTAKE MANIFOLD
THROTTLE VALVE
INJECTOR
INTAKE VALVE
SPRING
VALVE
CAMSHAFT
FUEL METERING UNIT
PRESSURE RELIEF VALVE
FUEL PUMP
FUEL FILTER
ACCELERATOR PEDAL
FUEL LINE BACK TO FUEL TANK
FUEL TANK

Figure 4-63. Mechanical-Timed Injection.

TA233425

120

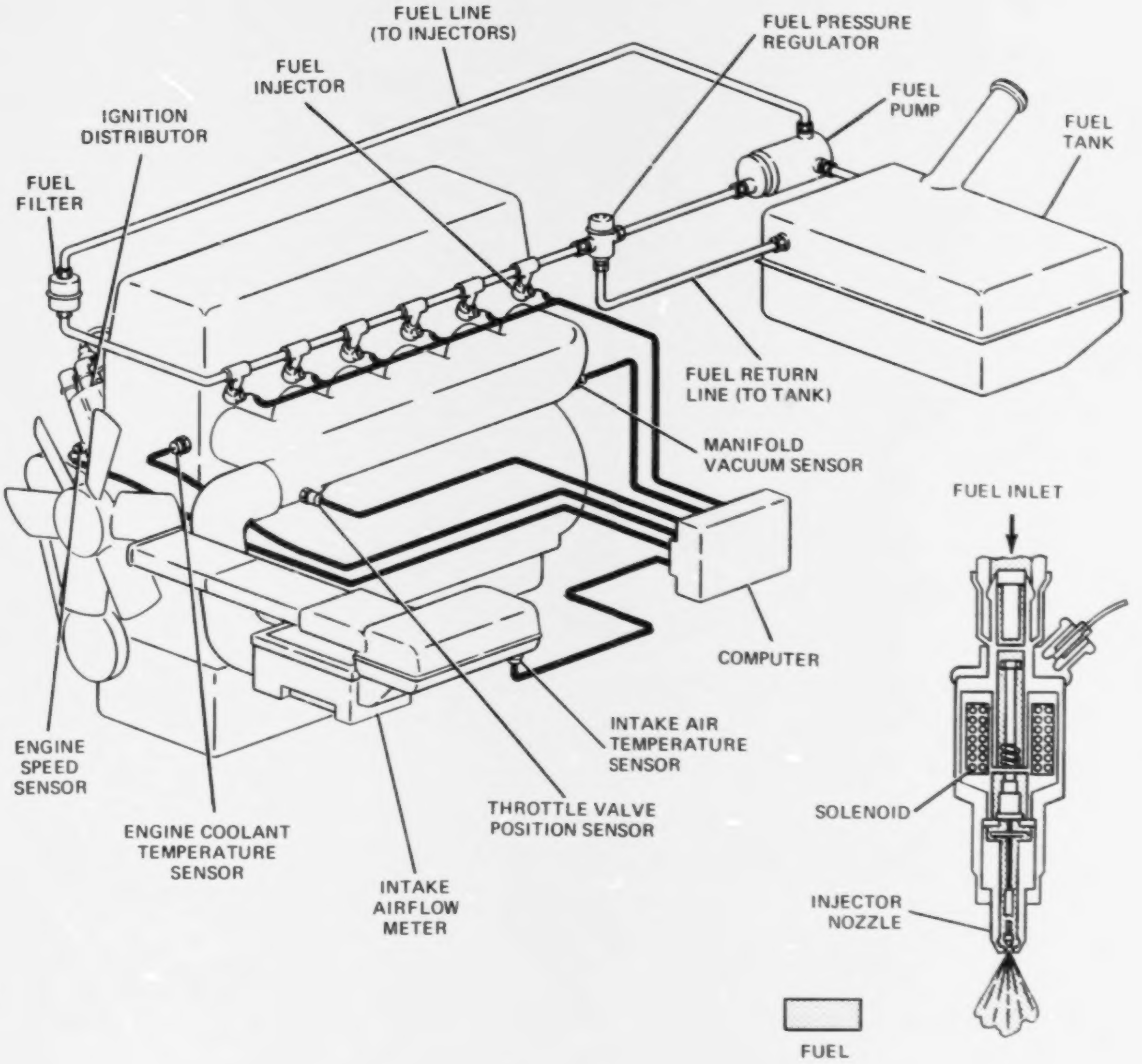

FUEL LINE (TO INJECTORS)
FUEL PRESSURE REGULATOR
FUEL INJECTOR
FUEL PUMP
FUEL TANK
IGNITION DISTRIBUTOR
FUEL FILTER
FUEL RETURN LINE (TO TANK)
MANIFOLD VACUUM SENSOR
FUEL INLET
COMPUTER
INTAKE AIR TEMPERATURE SENSOR
ENGINE SPEED SENSOR
THROTTLE VALVE POSITION SENSOR
SOLENOID
ENGINE COOLANT TEMPERATURE SENSOR
INTAKE AIRFLOW METER
INJECTOR NOZZLE
FUEL

Figure 4-64. Electronic-Timed Injection.

(5) Throttle valve position

(6) Intake manifold airflow.

The computer receives this information and uses it to calculate the amount of fuel delivered at each injection cycle. The computer is capable of changing the rate of fuel delivery to the engine hundreds of times a second, making the system extremely accurate. The computer regulates the amount of fuel delivered by varying the duration of injector operation.

4-27. Continuous Fuel Injection (Fig. 4-65). Continuous fuel injection systems provide a continuous spray of fuel from each injector at a point in the intake port located just before each intake valve.Because the entrance of the fuel into the cylinder is controlled by the intake valve, the continuous system will fulfill the requirements of a gasoline engine. Timed injection systems, though a necessity on diesel engines, are costlier than continuous systems and are used on gasoline engines only when more precise fuel metering is desired. In the

TA233426

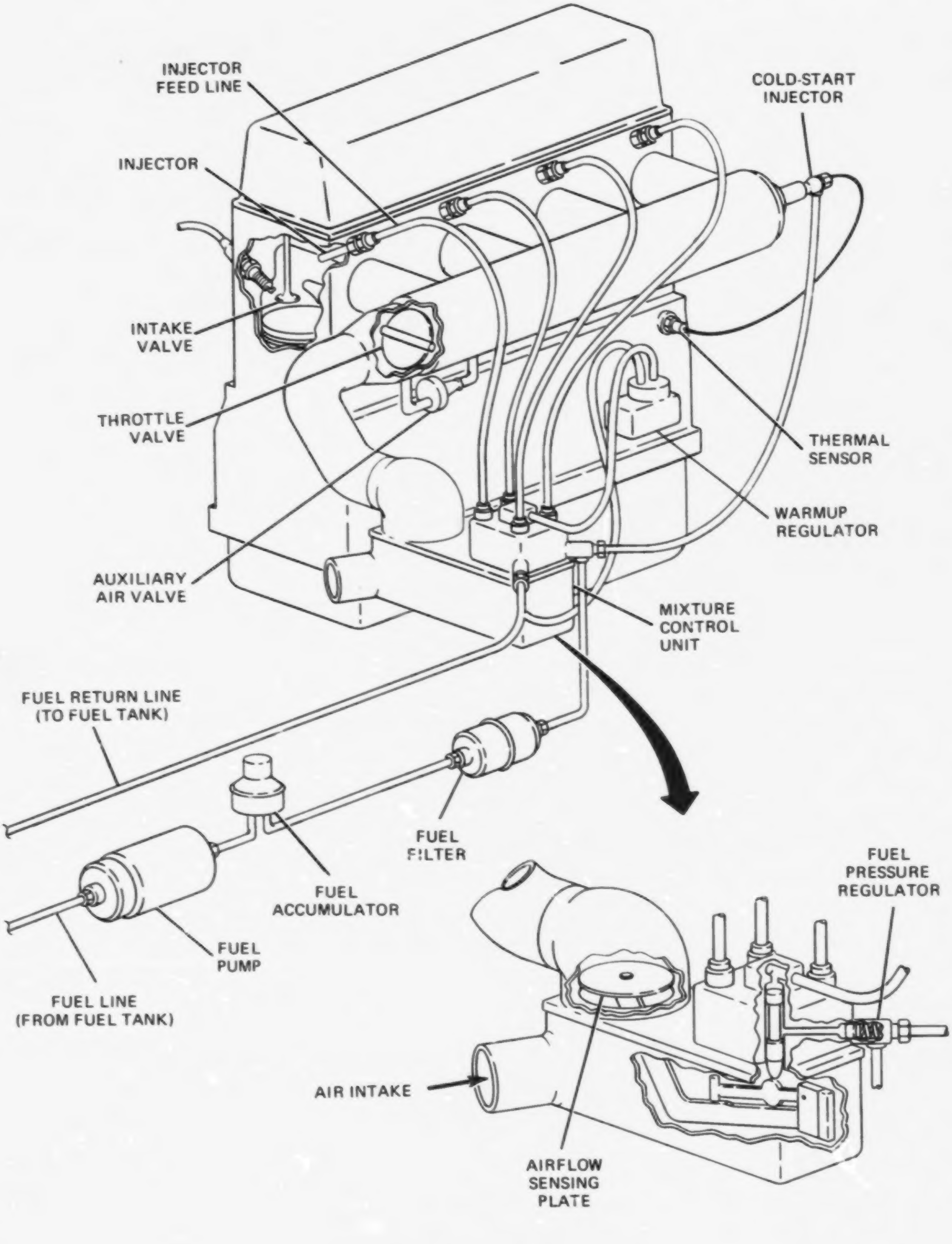

INJECTOR FEED LINE
COLD-START INJECTOR
INJECTOR
INTAKE VALVE
THROTTLE VALVE
THERMAL SENSOR
WARMUP REGULATOR
AUXILIARY AIR VALVE
MIXTURE CONTROL UNIT
FUEL RETURN LINE (TO FUEL TANK)
FUEL FILTER
FUEL PRESSURE REGULATOR
FUEL ACCUMULATOR
FUEL PUMP
FUEL LINE (FROM FUEL TANK)
AIR INTAKE
AIRFLOW SENSING PLATE

Figure 4-65. Continuous Injection.

TA233427

continuous system, fuel is delivered to the mixture control unit by the fuel pump. The fuel pressure regulator maintains fuel line pressure by sending excess fuel back to the gas tank. The mixture control unit regulates the amount of fuel that is sent to the injectors based on the amount of airflow through the intake and the engine temperature. The mixture control unit on mechanical systems will be operated by the airflow sensing plate and the warmup regulator. This information on electronic systems will be fed into a computer that will, in turn, regulate the fuel injection rate. The accelerator pedal will regulate the rate of airflow through the intake by opening and closing the throttle valve. A cold-start injector is installed in the intake to provide a richer mixture during engine startup and warmup. It is actuated by electric current from the thermal sensor whenever the temperature of the coolant is below a certain level. The cold-start injector works in conjunction with the auxiliary air valve. Its function is to speed up the engine idle during warmup. It also is actuated by the thermal sensor.

4-28. Throttle Body Injection (Fig. 4-66). Throttle body injection is a form of continuous injection that uses one or two injectors delivering gasoline to the engine from one central point in the intake manifold. Though throttle body injection does not provide the precise fuel distribution of the direct port injection described in the previous paragraph, it is much cheaper to produce, yet provides a much higher degree of precision fuel metering than a carburetor. The throttle body injection unit is usually an integral one, containing all of the major system components, in most cases. The unit mounts on the intake manifold in the same manner as a carburetor. Airflow sensors and electronic computers usually are mounted in the air cleaner body.

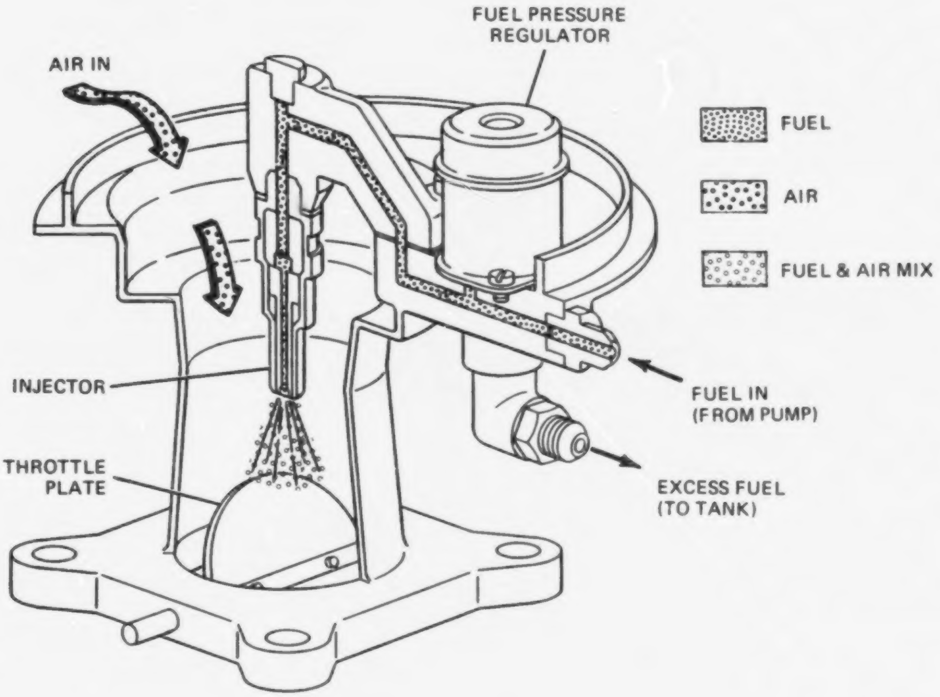


Figure 4-66. Throttle Body Injection.

TA233428

123

Section VI. TURBOCHARGERS AND SUPERCHARGERS

4-29. General. Turbocharging or supercharging is a method of increasing engine volumetric efficiency (para 2-23) by forcing the air-fuel mixture into the intake rather than merely allowing the pistons to draw it in naturally. Supercharging and turbocharging in some cases will push volumetric efficiencies over 100 percent. Engines must be modified to operate properly in some cases, because the extra air-fuel mixture will cause higher compression pressures, resulting in detonation (para 4-40c).

4-30. Turbochargers (Fig. 4-67). A turbocharger uses the force of the engine exhaust stream to force the air-fuel mixture into the engine. It consists of a housing containing two chambers. One chamber contains a turbine that is spun as hot exhaust gases are directed against it. The turbine shaft drives an impeller that is located in the other chamber. The spinning impeller draws an air-fuel mixture from the carburetor and forces it into the engine. Because the volume of exhaust gases increases with engine load and speed, the turbocharger speed will increase proportionally, keeping the manifold pressure boost fairly uniform. A device known as a waste gate is installed on turbocharged engines to control manifold pressure. It is a valve that, when open, allows engine exhaust to bypass the turbocharger turbine, effectively reducing intake pressure. The waste-gate valve is operated by a diaphragm that is operated by manifold pressure. The diaphragm will open the waste-gate valve whenever manifold pressure reaches the desired maximum.

4-31. Superchargers.

a. General. Superchargers are engine-driven air pumps that force the air-fuel mixture into the engine. They are made in three basic configurations: centrifugal, rootes, and vane.

b. Centrifugal Supercharger (Fig. 4-68). The centrifugal supercharger has an impeller equipped with curved vanes. As the impeller is driven by the engine, it draws air into its center and throws it off at its rim. The air then is pushed along the inside of the circular housing. The diameter of the housing gradually increases to the outlet where the air is pushed out. The air from the outlet then is routed to the carburetor via a pressure box (para 4-31e).

c. Rootes Supercharger (Fig. 4-69). The rootes supercharger is of the positive displacement type, and consists of two rotors inside a housing. As the rotors are driven by the engine, air is trapped between them and the housing. It then is carried to the outlet where it is discharged. The rotors and the housing in this type of supercharger must maintain very tight clearances and therefore are very sensitive to dirt.

d. Vane Supercharger (Fig. 4-70). The vane supercharger operates the same way as the vane oil pump described in paragraph 20-6. It is a positive displacement-type supercharger that usually is belt driven by the engine. The air output of the vane supercharger usually is routed to the carburetor via a pressure box (para 4-31e).

e. Pressure Box (Fig. 4-71). A large percentage of superchargers are situated so that they force air into the carburetor throat rather than drawing the mixture from the bottom of the carburetor. This creates a problem because it will cause pressure in the venturi that is higher than atmospheric. This, in turn, will cause air to be blown into the discharge nozzle rather than fuel being drawn out. The solution is to enclose the carburetor in a sealed pressure box. The outlet of the supercharger then pressurizes the pressure box, providing the necessary boost. A relief valve usually is provided on the box to prevent pressure in the box from exceeding a desired limit.

124

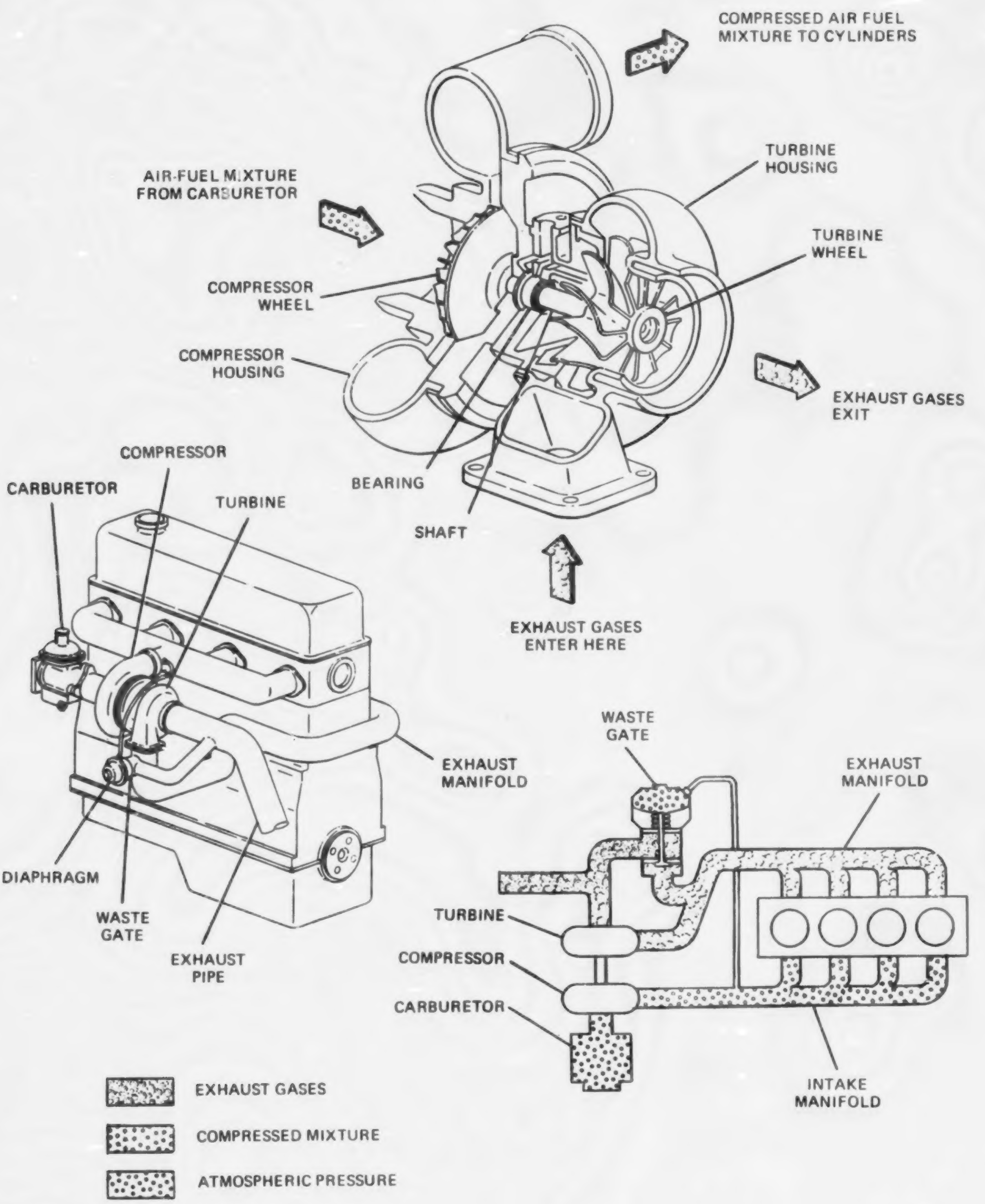

COMPRESSED AIR FUEL MIXTURE TO CYLINDERS
AIR-FUEL MIXTURE FROM CARBURETOR
TURBINE HOUSING
TURBINE WHEEL
COMPRESSOR WHEEL
COMPRESSOR HOUSING
EXHAUST GASES EXIT
COMPRESSOR
CARBURETOR
TURBINE
BEARING
SHAFT
EXHAUST GASES ENTER HERE
WASTE GATE
EXHAUST MANIFOLD
EXHAUST MANIFOLD
DIAPHRAGM
WASTE GATE
EXHAUST PIPE
TURBINE
COMPRESSOR
CARBURETOR
INTAKE MANIFOLD
EXHAUST GASES
COMPRESSED MIXTURE
ATMOSPHERIC PRESSURE

Figure 4-67. Turbocharger.

TA233429

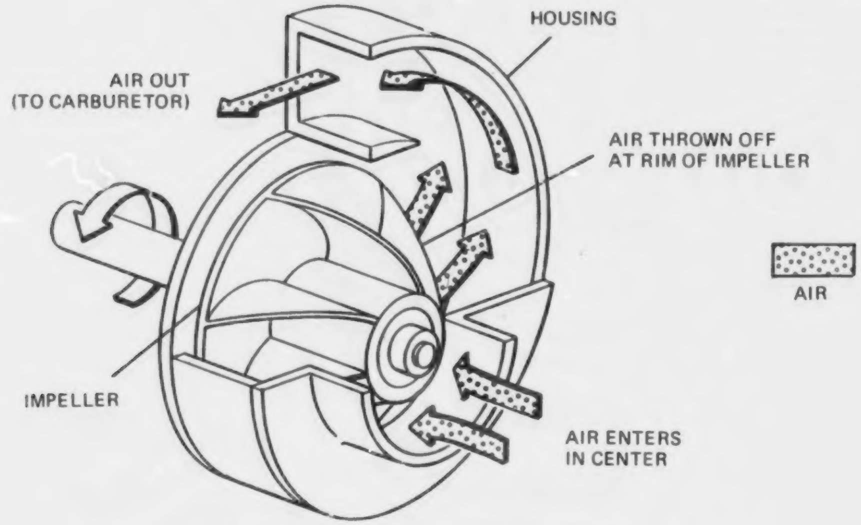
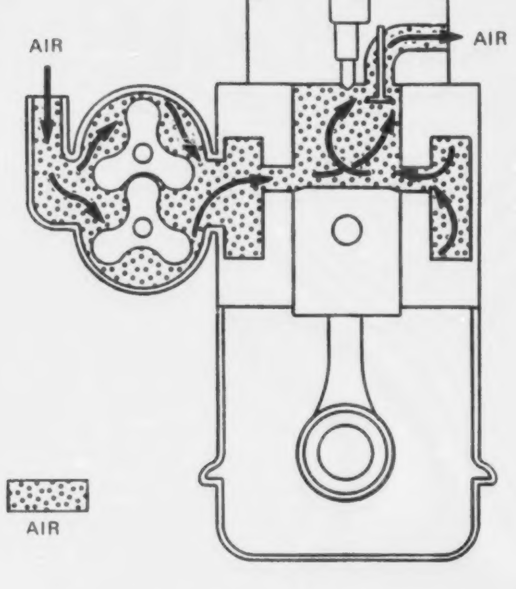

HOUSING
AIR OUT
(TO CARBURETOR)
AIR THROWN OFF
AT RIM OF IMPELLER
AIR
IMPELLER
AIR ENTERS
IN CENTER

Figure 4-68. Centrifugal Supercharger.



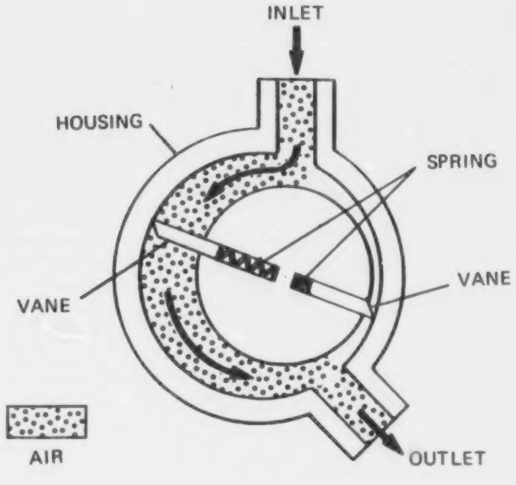

INLET
HOUSING
SPRING
VANE
VANE
AIR
OUTLET

Figure 4-69. Rootes Supercharger.

Figure 4-70. Vane-Type Supercharger.

TA233430

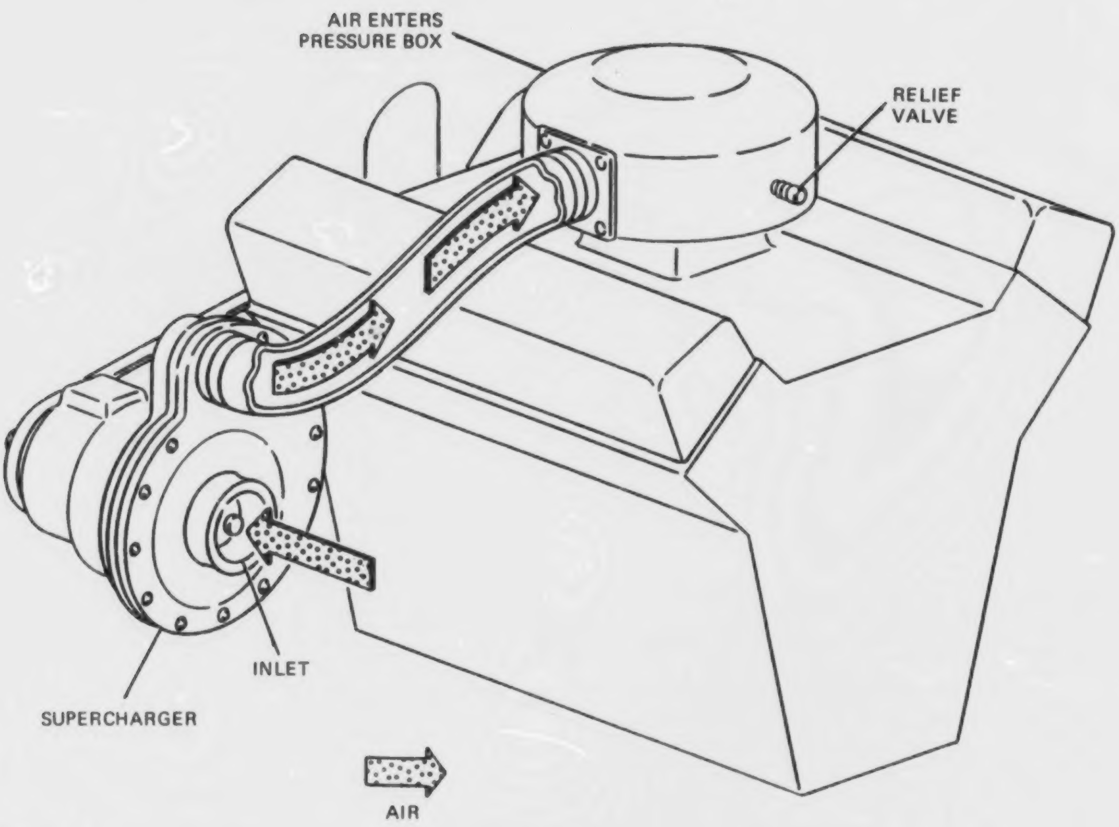


Figure 4-71. Pressure Box.

Section VII. GOVERNORS

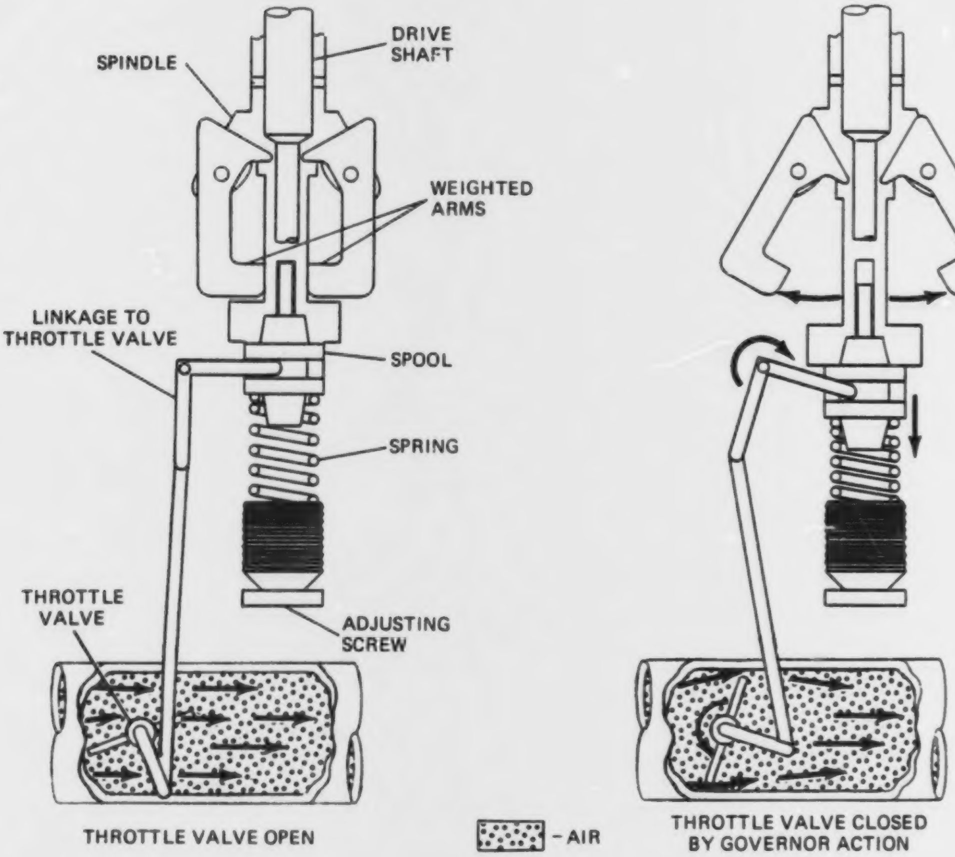
4-32. Purpose. Governors are used on automotive vehicles to regulate maximum engine speed and thus prevent excess engine wear. Testing has proven that the rate of engine wear increases by the square of engine speed. This means that in the higher speed ranges even a few hundred rpm speed increase will cause a tremendous wear increase. This section describes the various types of governors.

4-33. Centrifugal Governors (Fig. 4-72). A centrifugal governor is made up of two weighted arms pivoted on a spindle. The spindle and the arms are rotated by the engine through a drive shaft. The weights tend to swing outward from their center axis as they rotate. The outward movement of the weights will, through linkage, close an extra throttle valve that is installed in the carburetor throat. The operation of this throttle valve effectively will restrict engine speed. There is a spring installed on the governor that holds the weights in a normally closed position. The governor weights must reach sufficient speed as the engine rotates to develop enough centrifugal force to overcome the force of the spring before they swing out to operate the throttle valve. This means that the spring tension regulates engine speed. An adjustment is provided to adjust the governed engine speed. The adjustment is in the form of a screw that increases or decreases spring tension.

4-34. Velocity-Vacuum Governor. The velocity-vacuum govenor is operated by the speed of the air-fuel mixture passing the throttle plate. As the speed of the air-fuel mixture reaches a certain point, it will tend to push the throttle valve closed. This effectively will limit engine speed. In order for this to take place, the throttle shaft must be offset in the carburetor throat so that the moving mixture

TA233431

127



THROTTLE VALVE OPEN

THROTTLE VALVE CLOSED BY GOVERNOR ACTION

Figure 4-72. Centrifugal Governor.

will exert more pressure on one side of the throttle valve than on the other. Also, the throttle valve must be limited from opening all of the way. This is because the throttle valve could not be pushed closed during full throttle applications if it were perpendicular to mixture flow. The following two subparagraphs demonstrate the two variations of this type of governor.

a. Velocity-Vacuum Governor – Type I. The first type of centrifugal-vacuum governor (fig. 4-73) uses a spring that tends to pull the throttle toward the open position. The spring is attached on one end to a vacuum piston through an adjusting screw. The other end of the spring is attached to the throttle shaft through a lever. There is also a damper piston connected to this lever. Operation is as follows:

(1) As engine speed increases to the governed maximum, the speed of the mixture forces the throttle valve toward the closed position against the force of the governor spring.

(2) The damper piston prevents fluctuation of the throttle valve that would occur due to pulsation of the intake mixture caused by the time between, or the overlapping of, the intake strokes.

(3) During periods of light loads, the engine can reach its maximum governed speed with a relatively small throttle opening. This could cause the intake mixture to close the throttle valve too much, causing excessive speed reduction. To prevent this, a vacuum compensator piston uses manifold vacuum to increase the governor spring tension.

(4) The maximum governed engine speed can be adjusted by loosening or tightening the engine-speed adjusting screw, which changes the tension of the governor spring.

TA233432

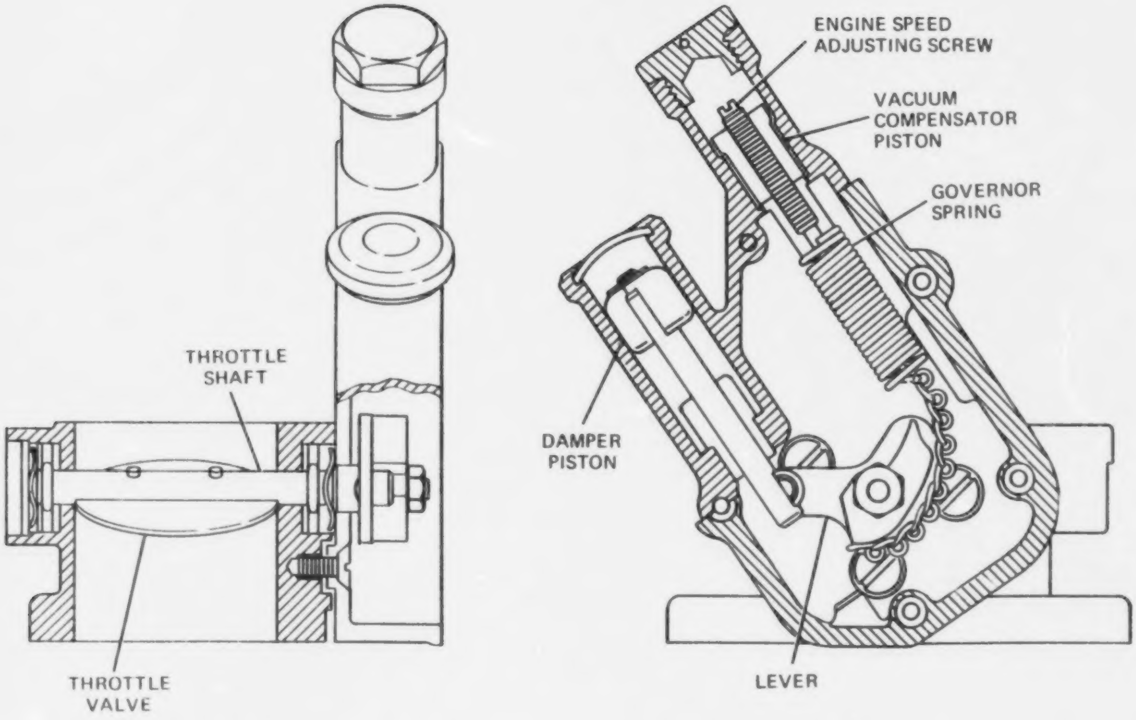


Figure 4-73. Velocity-Vacuum Governor – Type I.

b. Velocity-Vacuum Governor – Type II. The second type of velocity-vacuum governor (fig. 4-74) also uses a spring to pull the throttle valve toward the open position. One end of the spring is attached to the carburetor housing through an adjusting screw. The other end of the spring is attached to the throttle shaft through a flywheel that is attached to the end of the shaft. A compensator spring is located so that it operates with the throttle shaft during periods of small throttle opening. Operation is as follows:

(1) As engine speed increases to the governed maximum, the speed of the mixture forces the throttle valve toward the closed position against the force of the governor spring.

(2) The flywheel, by inertial force, prevents fluctuation of the throttle valve that would occur due to pulsation of the intake mixture caused by the time between, or the overlapping of, the intake strokes.

(3) During periods of light loads, the engine can reach its maximum governed speed with a relatively small throttle opening. This could cause the intake mixture to close the throttle valve too much, causing excessive speed reduction. To prevent this, an extra compensator spring is fitted to offer additional resistance to throttle valve closing during periods of small throttle opening.

(4) By loosening or tightening the engine-speed adjusting screw, the maximum engine speed can be adjusted. The screw accomplishes this by changing the tension of the governor spring.

4-35. Centrifugal-Vacuum Governor (Fig. 4-75). A centrifugal-vacuum governor consists of two units that work together to regulate maximum engine speed. One is the centrifugal unit that is mounted under the ignition distributor. The other is the vacuum unit that is mounted under the carburetor.

a. Centrifugal Unit. The centrifugal unit is driven by the engine at the ignition distributor drive. Its purpose is to control the vacuum unit based on engine speed. Operation is as follows:

TA233433

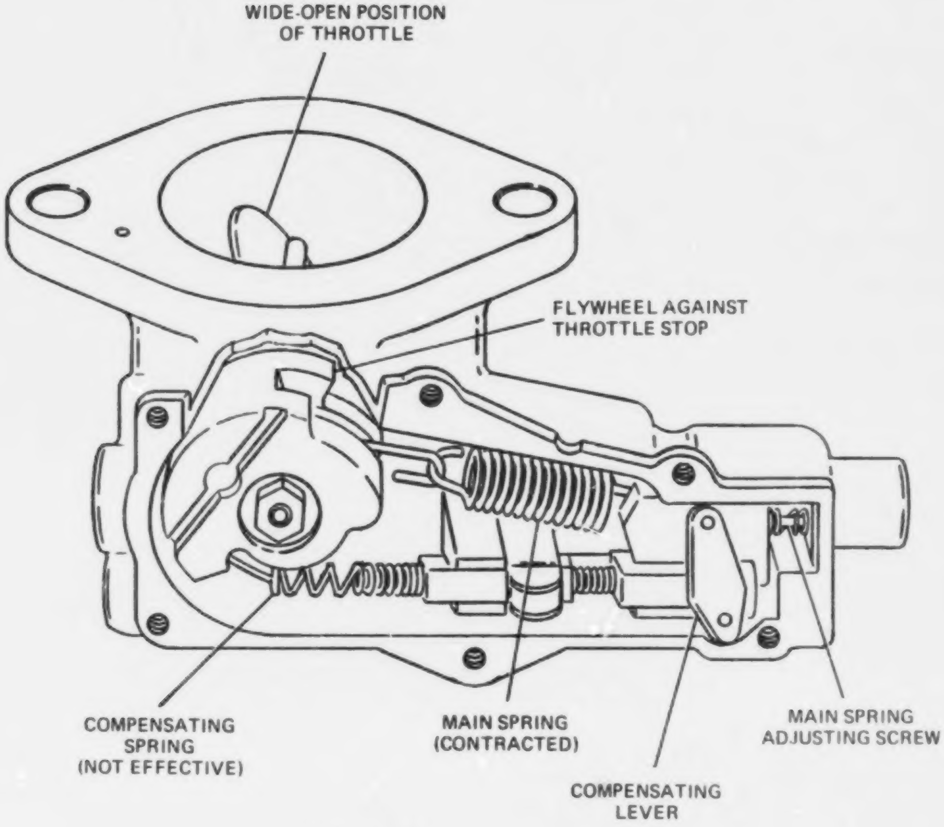

WIDE-OPEN POSITION OF THROTTLE
FLYWHEEL AGAINST THROTTLE STOP
COMPENSATING SPRING (NOT EFFECTIVE)
MAIN SPRING (CONTRACTED)
MAIN SPRING ADJUSTING SCREW
COMPENSATING LEVER

Figure 4-74. Velocity-Vacuum Governor – Type II.

(1) When the engine speed is below the governed maximum, the governor valve is held open by the valve spring. This allows atmospheric pressure to bleed into the valve and, through the governor vacuum line, equalize pressure in the vacuum unit. The vacuum unit is ineffective in this position.

(2) As engine speed approaches the governed maximum, the governor valve is seated by centrifugal force against the valve seat. This shuts off atmospheric pressure to the lower part of the vacuum unit allowing vacuum passages from the carburetor to reduce pressure. Atmospheric pressure in the upper part of the vacuum unit will then push the diaphragm down, causing the vacuum unit to limit engine speed.

b. Vacuum Unit. The vacuum unit is basically a diaphragm with a rod connecting it to the throttle valve shaft. When pressure is equal above and below the diaphragm, the governor spring pulls the diaphragm rod into a nongoverning position. When pressure drops under the diaphragm, as dictated by the governor valve, atmospheric pressure will push the diaphragm down against the force of the governor spring, causing the diaphragm rod to pull the throttle valves toward the closed position. This effectively will limit engine speed.

TA233434

130

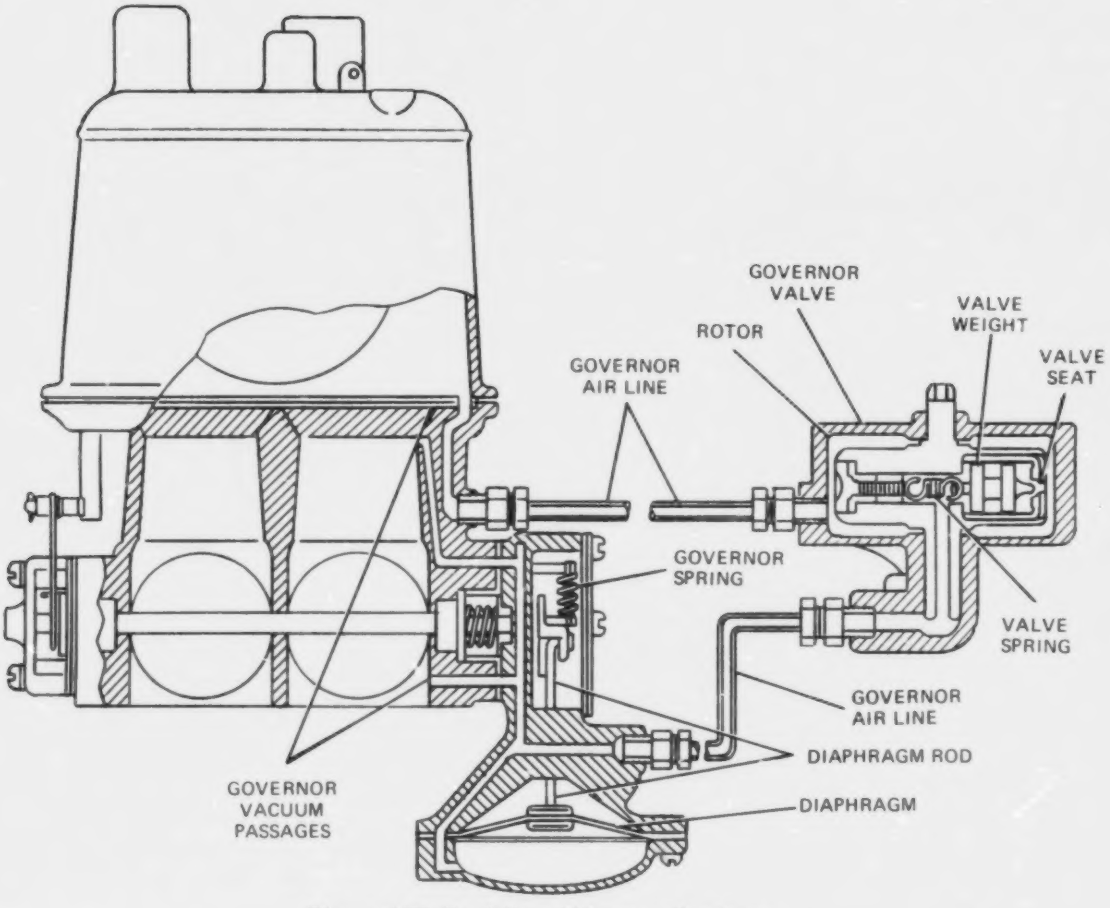


Figure 4-75. Centrifugal-Vacuum Governor.

Section VIII. CHARACTERISTICS OF GASOLINE

4-36. Origin. Petroleum is the most common source of fuel for modern internal combustion engines. It contains two important elements: carbon and hydrogen. These elements are in such proportions that they will burn freely in air and liberate heat energy. Petroleum contains a tremendous amount of potential energy. In comparison to dynamite, in fact, a gallon of gasoline has six times as much potential energy. Gasoline is the most popular petroleum-based engine fuel. It has many advantages, two of which are a better rate of burning and easy vaporization to give quick starting in cold weather. The major characteristics of gasoline that affect engine operation are volatility, purity, and antiknock quality (octane rating).

4-37. Volatility in Gasoline. Volatility, as applied to gasoline, is its tendency to change from liquid to vapor at any given temperature. The volatility of gasoline affects ease of starting, length of warmup period, and engine performance during normal operation. The rate of vaporization increases as the temperature increases and as pressure decreases. The volatility of gasoline must be regulated carefully so that it is volatile enough to provide acceptable cold weather starting, yet not be so volatile that it is subject to vapor lock during normal operation. Refiners introduce additives to gasoline to control volatility according to regional climates and seasons.

a. Starting Ability. To provide satisfactory cold weather performance and starting, the choke system causes a very rich mixture to be delivered to the engine. Gasoline that is not volatile enough will cause excessive amounts of

TA233435

raw unvaporized fuel to be introduced to the combustion chambers. Because unvaporized fuel does not burn, it is wasted. This reduces fuel economy and causes a condition known as crankcase dilution.

b. Crankcase Dilution. Crankcase dilution occurs when the fuel that is not vaporized leaks past the piston rings and seeps into the crankcase. The unvaporized fuel then dilutes the engine oil, reducing its lubricating qualities.

A certain amount of crankcase dilution occurs in all engines during warmup. It is not considered harmful in normal quantities because it vaporizes out of the oil as the engine warms up. The vapors then are purged by the crankcase ventilation system (para 7-7).

c. Vapor Lock. Vapor lock is one of the difficulties experienced in hot weather when using highly volatile fuels. When fuel has a tendency to vaporize at normal atmospheric temperature, it may form so much vapor in the fuel line that the action of the fuel pump will cause a pulsation of the fuel vapor rather than normal fuel flow. Heat insulating materials or baffles are often placed between the exhaust pipe and fuel line to help avoid vapor lock. Hot-weather grades of gasoline are blended from lower volatility fuels to lessen the tendency toward vapor lock.

d. Fuel Distribution. When the fuel is not distributed evenly to all cylinders, the engine will run unevenly and power output will decrease. To ensure good distribution, the fuel must be vaporized completely and mixed with air in the manifold before entering the combustion chamber.

4-38. Purity. Petroleum contains many impurities that must be removed during the refining process before gasoline suitable for automotive use is produced. At one time, considerable corrosion was caused by the sulfur inherent in petroleum products, but modern refining processes have made it almost negligible. Another problem was the tendency for the hydrocarbons in the gasoline to oxidize into a sticky gum when exposed to air, which resulted in clogged carburetor passages, stuck valves, and other operational difficulties. Chemicals that control gumming are now added to gasoline. Dirt, grease, water, and various chemicals also must be removed to make gasoline an acceptable fuel.

4-39. Deicing Agents. Moisture in gasoline tends to freeze in cold weather, causing clogged fuel lines and carburetor idle ports. Deicing agents are added to gasoline that mix with the moisture and act as an antifreeze to prevent freezing.

4-40. Antiknock Quality.

a. Combustion. To understand what is meant by antiknock quality, first review the process of combustion. When any substance burns, it actually is uniting in rapid chemical reaction with oxygen (one of the constituents of air). During this process, the molecules of the substance and oxygen are set into very rapid motion and heat is produced. In the combustion chamber of an engine cylinder, the gasoline vapor and oxygen in the air are ignited and burn. They combine, and the molecules begin to move about very rapidly as the high temperatures of combustion are reached. The molecules, therefore, bombard the combustion chamber walls and the piston head with a shower of fast moving molecules. It is actually this bombardment that registers the heavy push on the piston and forces it downward on the power stroke.

b. Combustion Process. The normal combustion process in the combustion chamber (fig. 4-76) goes through three stages when producing power. They are as follows:

(1) *Formation of Nucleus of Flame.* As soon as a spark jumps the gap of the spark plug electrode, a small ball of blue flame develops in the gap. This ball is the first stage, or nucleus, of the flame. It enlarges with relative slowness and,

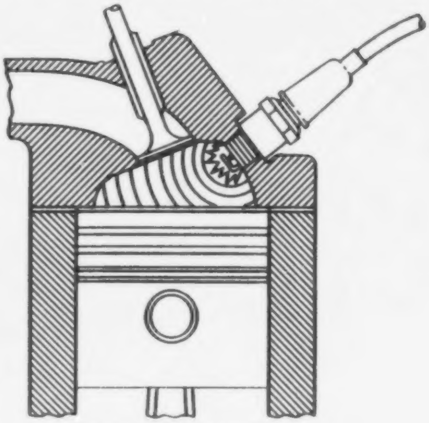


Figure 4-76. Normal Combustion.

TA233436

132

during its growth, there is no measurable pressure created by heat.

(2) *Hatching Out.* As the nucleus enlarges, it develops into the hatching out stage. The nucleus is torn apart so that it sends fingers of flame into the mixture in the combustion chamber. This causes enough heat to give just a slight rise in the temperature and pressure in the entire air-fuel mixture. Consequently, a lag still exists in the attempt to raise pressure in the entire cylinder.

(3) *Propagation.* It is during the third, or propagation, stage that effective burning occurs. The flame now burns in a front that sweeps across the combustion chamber, burning rapidly and causing great heat with an accompanying rise in pressure. This pressure causes the piston to move downward. The burning during normal combustion is progressive. It increases gradually during the first two stages, but during the third stage, the flame is extremely strong as it sweeps through the combustion chamber.

c. Detonation (Fig. 4-77). If detonation takes place, it will happen during the third stage of combustion. The first two stages are normal, but in the propagation stage, the flame sweeps from the area around the spark plug toward the walls of the combustion chamber. Parts of the chamber that the flame has passed contain inert gases, but the section not yet touched by the flame contains highly compressed, heated combustible gases. As the flame races through the combustion chamber, the unburned gases ahead of it are further compressed and are heated to high temperatures. Under certain conditions, the extreme heating of the unburned part of the mixture may cause it to ignite spontaneously and explode. This rapid, uncontrolled burning in the final stage of combustion is called detonation. It is caused by the rapidly burning flame front compressing the unburned part of the mixture to the point of self-ignition. This secondary wave front collides with the normal wave front, making an audible knock or ping. It is an uncontrolled explosion, causing the unconfined gases in the combustion chamber to rap against the cylinder head walls. Detonation may harm an engine or hinder its performance in several ways. In extreme cases, pistons have been shattered, rings broken, or heads cracked. Detonation also may cause overheating, excessive bearing wear, loss of power, and high fuel consumption.

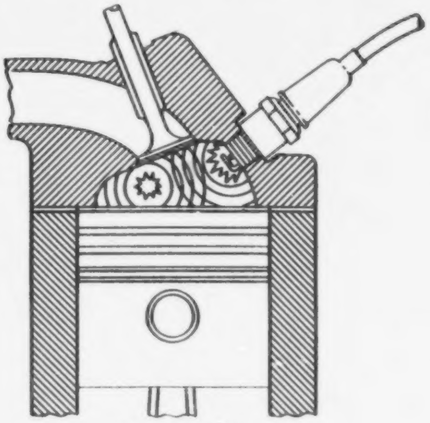


Figure 4-77. Detonation.

d. Octane Rating.

(1) The ability of a fuel to resist detonation is measured by its octane rating. The octane rating of a fuel is determined by matching it against mixtures of normal heptane and iso-octane in a test engine under specified test conditions until a pure mixture of hydrocarbons is found that gives the same degree of knocking in the engine as the gasoline being tested. The octane number of the gasoline then is specified as the percent of the iso-octane in the matching iso-octane, normal-heptane mixture. For example, a gasoline rating of 75 octane is equivalent in its knocking characteristics to a mixture of 75 percent iso-octane and 25 percent normal heptane. Thus, by definition, normal heptane has an octane rating of 0 and iso-octane has an octane of 100.

(2) The tendency of a fuel to detonate varies in different engines and in the same engines under different operating conditions. The octane number has nothing to do with starting qualities, potential energy, volatility, or other major characteristics. Engines are designed to operate within a certain octane range. Performance is improved with the use of higher octane fuels within that operational range. Engine performance will not be improved if a gasoline with an octane rating higher than the operational range is provided.

(3) Tetraethyl lead is the most popular of the compounds added to gasoline to raise its octane rating. The introduction of catalytic con-

TA233437

verters, however, has created a need for a higher octane lead-free gasoline that is produced by more careful refining processes and numerous substitutes for lead. Lead-free gasolines to date, however, do not have the antiknock qualities of leaded ones. Modern automotive engines made for use with lead-free gasoline, therefore, must be designed for lower octane ratings.

e. Other Causes for Knocking.

(1) Low-octane fuel is not the only reason for knocking. Anything that adds heat or pressure to the last part of the mixture to burn within a cylinder will aggravate detonation and also result in knocking. That is why the compression ratio of a gasoline engine has an upper limit. When the ratio is raised too high, the immediate result is detonation caused by excessive heat from the additional compression. Under certain conditions, excessive spark advance, lean fuel mixtures, and defective cooling systems are a few of the many causes of detonation.

(2) Preignition is another cause for knocking (fig. 4-78). Though its symptoms are similar, it is not to be confused with detonation. Preignition is an igniting of the air-fuel mixture during compression before the spark occurs and is caused by some form of hot spot in the cylinder, such as an overheated exhaust valve head or spark plug, or a glowing piece of carbon. Preignition can lead to detonation, but the two are separate and distinct events.

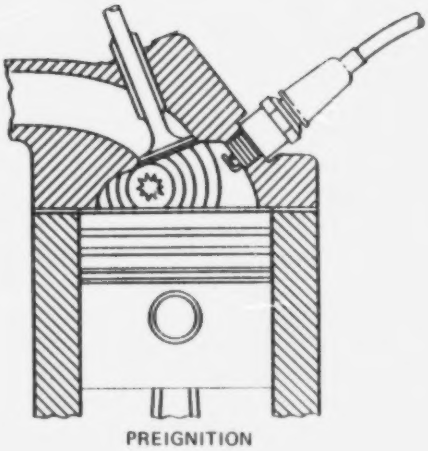


Figure 4-78. Preignition.

TA233438

134

CHAPTER 5

DIESEL FUEL SYSTEMS

Section I. CHARACTERISTICS OF DIESEL FUELS

5-1. General. The fuels used in modern high-speed diesel engines are derived from the heavier residues of the crude oil that are left over after the more volatile fuels such as gasoline and kerosene are removed during the refining process. The large, slow running diesel engines used in stationary or marine installations will burn almost any grade of heavy fuel oil. This contrasts with the smaller, high-speed diesel engines that require a fuel oil that is as light as kerosene. Although diesel fuels are considered residue of the refining process, their specification requirements are just as exacting as gasoline.

5-2. Cleanliness. Probably the most important characteristic of diesel fuels is cleanliness. Any foreign material present in diesel fuel will certainly cause damage to the finely machined injector parts. Damage occurs in two ways:

a. Particles of dirt cause scoring of the injector components.

b. Moisture in the fuel will cause corrosion of the injector components.

Any damage to the fuel injectors will cause poor operation or render the engine inoperative. Controlling dirt and moisture content in diesel fuel is more difficult because it is heavier than gasoline. This causes foreign material to remain in suspension longer so that sediment bowls (para 4-2) do not work as well as with gasoline fuel systems.

5-3. Viscosity. The viscosity of a fluid is an indication of its resistance to flow. What this means is that a fluid with a high viscosity is heavier than a fluid with a low viscosity. The viscosity of diesel fuel must be low enough to flow freely at its lowest operational temperature, yet high enough to provide lubrication to the moving parts of the finely machined injectors. The fuel must also be sufficiently viscous so that leakage at the pump plungers and dribbling at the injectors will not occur. Viscosity also will determine the size of the fuel droplets, which, in turn, govern the atomization and penetration qualities of the fuel injector spray.

5-4. Ignition Quality. The ignition quality of a fuel is its ability to ignite spontaneously under the conditions existing in the engine cylinder. The spontaneous-ignition point of a diesel fuel is a function of the pressure, temperature, and time. Because it is difficult to reproduce the operating conditions of the fuel artificially outside the engine cylinder, a diesel engine operating under controlled conditions is used to determine the ignition quality of diesel fuel. The yardstick that is used to measure the ignition quality of a diesel fuel is the cetane-number scale. The cetane number of a fuel is obtained by comparing it to the operation of a reference fuel. The reference fuel is a mixture of alpha-methyl-naphthalene, which has virtually no spontaneous-ignition qualities, and pure cetane, which has what are considered to be perfect spontaneous-ignition qualities. The percentage of cetane is increased gradually in the reference fuel until the fuel matches the spontaneous-ignition qualities of the fuel being tested. The cetane number then is established for the fuel being tested based on the percentage of cetane present in the reference mixture.

5-5. Knocking. Diesel engines have a tendency to produce a knock that is noticeable particularly during times when the engine is under a light load. This knocking occurs due to a condition known as ignition delay or ignition lag. When the power stroke begins, the first molecules of fuel injected into the combustion chamber first must vaporize and superheat before ignition occurs. During this period, a quantity of unburned fuel builds up in the combustion chamber. When ignition occurs, the pressure increase causes the built-up fuel to ignite instantly. This causes a disproportionate increase in pressure, creating a distinct and audible knock. Increasing the compression ratio of a diesel engine will decrease ignition lag and the tendency to knock. This contrasts with a gasoline engine, whose tendency to knock will increase with an increase in compression ratio. Knocking in diesel engines is affected by factors other than compression ratio, such as the type of combustion chamber, airflow within the chamber, injector nozzle type, air and fuel temperature, and the cetane number of the fuel.

135

5-6. Multifuel Engine Authorized Fuels. Multifuel engines are four-stroke cycle diesel engines that will operate satisfactorily on a wide variety of fuels. The fuels are grouped accordingly:

a. Primary and Alternate I Fuels. These fuels will operate the multifuel engine with no additives.

b. Alternate II Fuels. These fuels generally require the addition of diesel fuel to operate the multifuel engine.

c. Emergency Fuels. These fuels will operate the multifuel engine with the addition of diesel fuel. Extended use of fuels from this group will cause eventual fouling of fuel injection components.

It should be noted that there are no adjustments necessary to the engine when changing from one fuel to another.

5-7. Fuel Density Compensator (Fig. 5-1). The multifuel engine operates on a variety of fuels that have a broad range of viscosities and heat values. These variations in the fuels affect engine output. Because it is unacceptable for the power output of the engine to vary with fuel changes, the multifuel engine is fitted with a device known as a fuel density compensator. The fuel density compensator is a device that serves to vary the quantity of fuel injected to the engine by regulating the full-load stop of the fuel pump (para 4-3). The characteristics of the fuels show that their heat values decrease almost inversely proportional to their viscosities. The fuel density compensator uses viscosity as the indicator for regulating fuel flow. Its operation is as follows:

a. The fuel supply enters the compensator through the fuel pressure regulator, where the supply pressure is regulated to a constant 20 psi regardless of engine speed and load range.

b. The pressure regulated fuel then passes through a series of two orifices. The two orifices, by offering greatly different resistances to flow, form a system that is sensitive to viscosity changes.

(1) The first orifice is annular, formed by the clearance between the servo piston and its cylinder. This orifice is sensitive to viscosity.

(2) The second orifice is formed by an adjustable needle valve, and, unlike the first, it is not viscosity sensitive.

(3) After the fuel passes through the two orifices it leaves the compensator through an outlet port. From here the fuel passes back to the pump.

c. The higher the viscosity of the fuel, the more trouble that it will have passing through the first orifice. Because of this, the fuel pressure under the servo piston will rise proportionally with viscosity. Because the second orifice is not viscosity sensitive, the pressure over the servo piston will remain fairly constant. This will cause a pressure differential that increases proportionally with viscosity, that in turn will cause the piston to seek a position in its bore that becomes higher as viscosity increases.

d. The upward movement of the servo piston will move a wedge-shaped moveable plate, which will increase fuel delivery. A lower viscosity fuel will cause the piston to move downward, causing the pump to decrease fuel delivery.

136

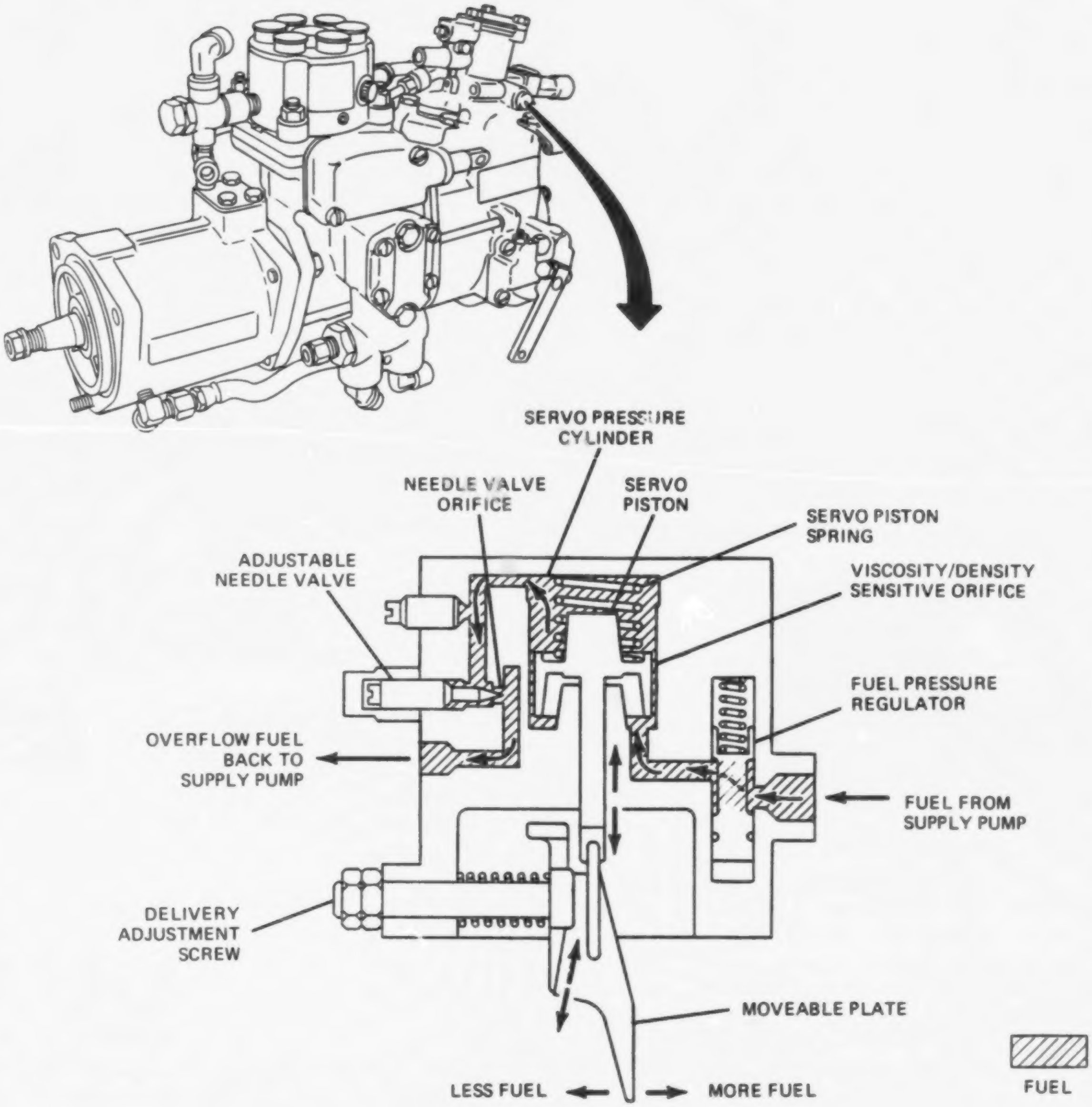

SERVO PRESSURE CYLINDER
NEEDLE VALVE ORIFICE
SERVO PISTON
SERVO PISTON SPRING
ADJUSTABLE NEEDLE VALVE
VISCOSITY/DENSITY SENSITIVE ORIFICE
FUEL PRESSURE REGULATOR
OVERFLOW FUEL BACK TO SUPPLY PUMP
FUEL FROM SUPPLY PUMP
DELIVERY ADJUSTMENT SCREW
MOVEABLE PLATE
LESS FUEL
MORE FUEL
▨ FUEL

Figure 5-1. Fuel Density Compensator.

Section II. COMBUSTION CHAMBER DESIGN

5-8. General. The fuel injected into the combustion chamber must be mixed thoroughly with the compressed air and distributed as evenly as possible throughout the chamber if the engine is to function at maximum efficiency and exhibit maximum driveability. The well-designed diesel engine uses a combustion chamber that is designed for the engine's intended usage. The injectors used in the engine should compliment the combustion chamber. The combustion chambers described in the following paragraphs are the most common and cover virtually all of the designs that are used in current automotive designs.

TA233439

5-9. Open Chamber (Fig. 5-2). The open chamber is the simplest form of chamber. It is suitable only for slow-speed, four-stroke cycle engines, but is used widely in two-stroke cycle diesel engines. In the open chamber, the fuel is injected directly into the space at the top of the cylinder. The combustion space, formed by the top of the piston and the cylinder head, usually is shaped to provide a swirling action of the air as the piston comes up on the compression stroke. There are no special pockets, cells, or passages to aid the mixing of the fuel and air. This type of chamber requires a higher injection pressure and a greater degree of fuel atomization than is required by other combustion chambers to obtain an acceptable level of fuel mixing. This chamber design is very susceptible to ignition lag.

5-10. Precombustion Chamber (Fig. 5-3). The precombustion chamber is an auxiliary chamber at the top of the cylinder. It is connected to the main combustion chamber by a restricted throat or passage. The precombustion chamber conditions the fuel for final combustion in the cylinder. A hollowed-out portion of the piston top causes turbulence in the main combustion chamber as the fuel enters from the precombustion chamber to aid in mixing with air. The following steps occur during the combustion process:

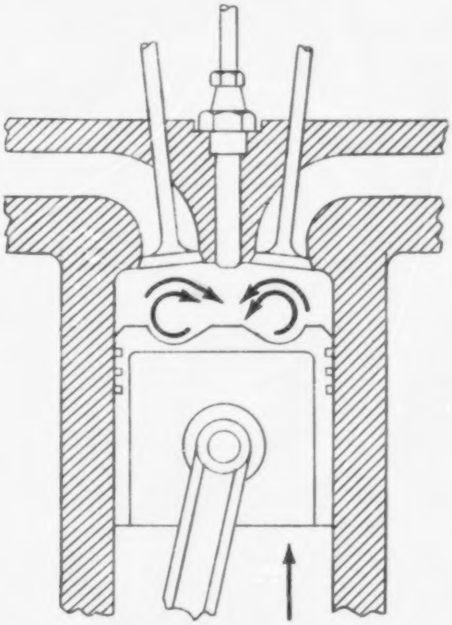


Figure 5-2. Open Combustion Chamber.

a. During the compression stroke of the engine, air is forced into the precompression chamber and, because the air compressed, it is hot. At the beginning of injection, the precombustion chamber contains a definite volume of air.

b. As the injection begins, combustion begins in the precombustion chamber. The burning of the fuel combined with the restricted passage to the main combustion chamber creates a tremendous amount of pressure in the precombustion chamber. The pressure and the initial combustion cause a superheated fuel charge to enter the main combustion chamber at a tremendous velocity.

c. The entering mixture hits the hollowed-out piston top, creating turbulence in the chamber to ensure complete mixing of the fuel charge with the air. This mixing ensures even and complete combustion. This chamber design will provide satisfactory performance with low fuel injector pressures and coarse spray patterns because a large amount of vaporization takes place in the combustion chamber. This chamber also is not very susceptible to ignition lag, making it more suitable for high-speed applications.

5-11. Turbulence Chamber (Fig. 5-4). The turbulence chamber is similar in appearance to the precombustion chamber, but its function is different. There is very little clearance between the top of the piston and the head, so that a high percentage of the air between the piston and the cylinder head is forced into the turbulence chamber during the compression stroke. The chamber usually is spherical, and the opening through which the air must pass becomes smaller as the piston reaches the top of the stroke, thereby increasing the velocity of the air in the chamber. This turbulence speed is approximately 50 times crankshaft speed. The fuel injection is timed to occur when the turbulence in the chamber is the greatest. This ensures a thorough mixing of the fuel and the air, with the result that the greater part of combustion takes place in the turbulence chamber itself. The pressure created by the expansion of the burning gases is the force that drives the piston downward on the power stroke.

5-12. Spherical Combustion Chamber (Fig. 5-5). The spherical combustion chamber is

TA233440

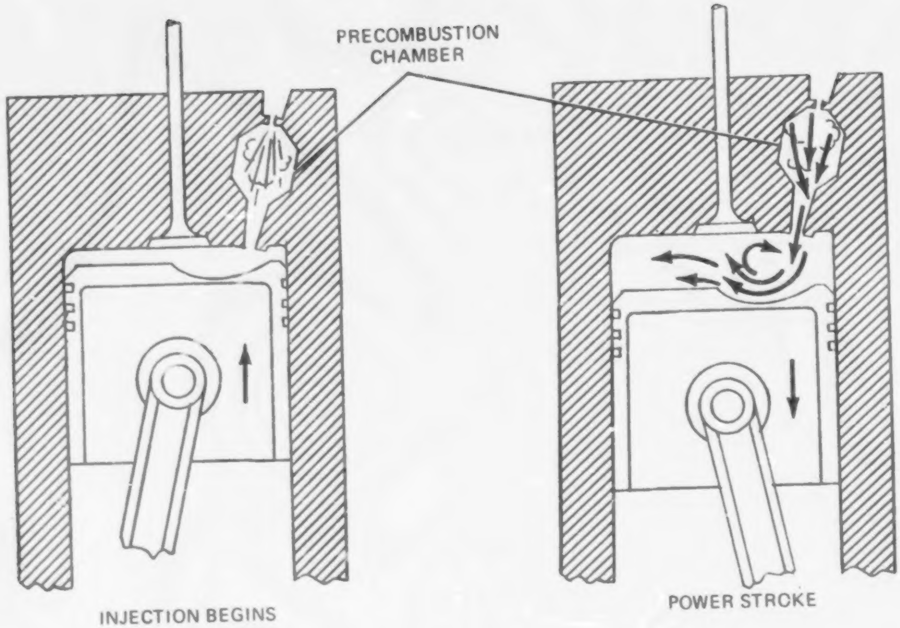

PRECOMBUSTION CHAMBER
INJECTION BEGINS
POWER STROKE

Figure 5-3. Precombustion Chamber.

designed principally for use in the multifuel engine. The chamber consists of a basic open-type chamber with a spherical-shaped relief in the top of the piston head. The chamber works in conjunction with a strategically positioned injector and an intake port that produces a swirling effect on the intake air as it enters the chamber. Operation of the chamber is as follows:

a. As the air enters the combustion chamber, a swirl effect is introduced to it by the shape of the intake port (A, fig. 5-5).

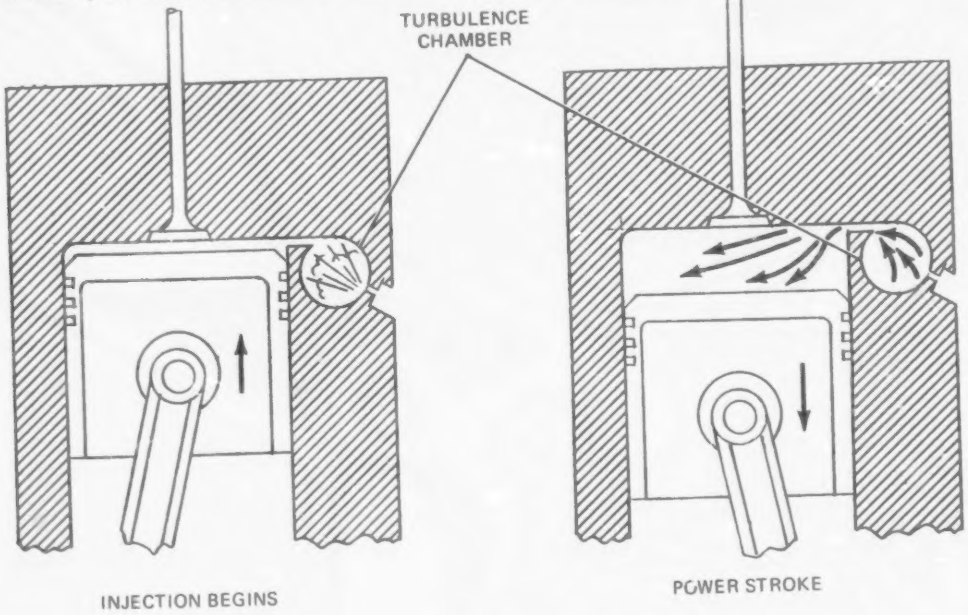
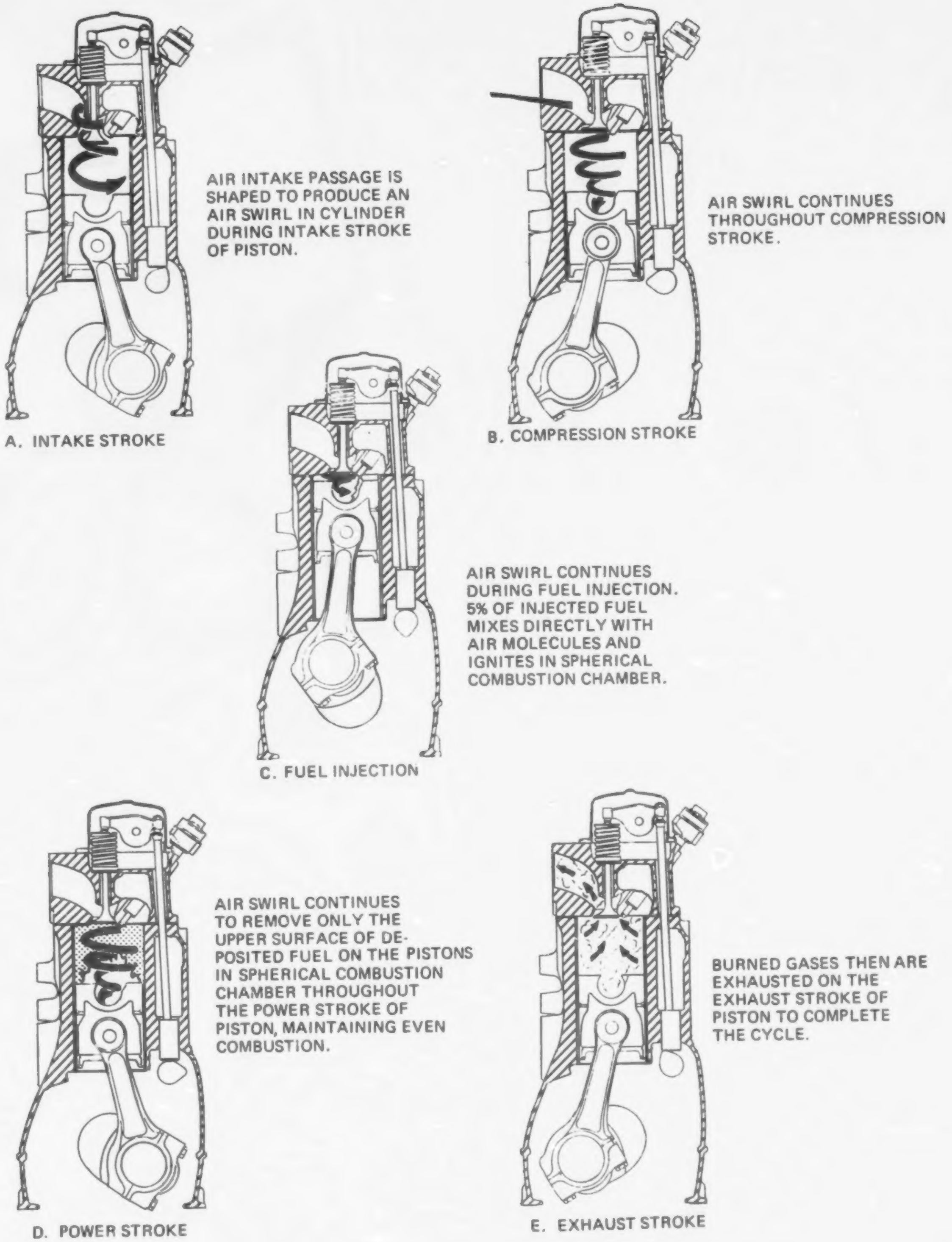

TURBULENCE CHAMBER
INJECTION BEGINS
POWER STROKE

Figure 5-4. Turbulence Chamber.

TA233441



A. INTAKE STROKE

AIR INTAKE PASSAGE IS SHAPED TO PRODUCE AN AIR SWIRL IN CYLINDER DURING INTAKE STROKE OF PISTON.

B. COMPRESSION STROKE

AIR SWIRL CONTINUES THROUGHOUT COMPRESSION STROKE.

C. FUEL INJECTION

AIR SWIRL CONTINUES DURING FUEL INJECTION. 5% OF INJECTED FUEL MIXES DIRECTLY WITH AIR MOLECULES AND IGNITES IN SPHERICAL COMBUSTION CHAMBER.

D. POWER STROKE

AIR SWIRL CONTINUES TO REMOVE ONLY THE UPPER SURFACE OF DEPOSITED FUEL ON THE PISTONS IN SPHERICAL COMBUSTION CHAMBER THROUGHOUT THE POWER STROKE OF PISTON, MAINTAINING EVEN COMBUSTION.

E. EXHAUST STROKE

BURNED GASES THEN ARE EXHAUSTED ON THE EXHAUST STROKE OF PISTON TO COMPLETE THE CYCLE.

Figure 5-5. Spherical Chamber.

TA233442

b. During the compression stroke, the swirling motion of the air continues as the temperature in the chamber increases (B, fig. 5-5).

c. As the fuel is injected, approximately 95 percent of it is deposited on the head of the piston and the remainder mixes with the air in the spherical combustion chamber (C, fig. 5-5).

d. As combustion begins, the main portion of the fuel is swept off of the piston head by the high-velocity swirl that was created by the intake and the compression strokes. As the fuel is swept off of the head, it burns through the power stroke, maintaining even combustion and eliminating detonation (D and E, fig. 5-5).

Section III. INJECTION SYSTEMS

5-13. Fuel Injection Principles.

a. *Methods.* There are two methods of injecting fuel into a compression-ignition engine. One method is air injection. This method uses a blast of air to force a measured charge of fuel into the combustion chamber. The other method is solid injection, where direct mechanical pressure is placed on the fuel itself to force it into the combustion chamber. This chapter only will cover solid injection systems because air injection virtually is unused in automotive applications.

b. *Fuel Atomization and Penetration.* The fuel spray entering the combustion chamber must conform to the chamber's shape so that the fuel particles will be well distributed and thoroughly mixed with the air. The shape of the spray is determined by the degree of atomization and penetration produced by the orifice through which the fuel enters the chamber. Atomization (para 4-9e) is the term used to indicate the size of the droplets the fuel is broken down into. Penetration is the distance from the orifice that the fuel droplets attain at a given phase of the injection period. The dominant factors that control penetration are the length of the nozzle orifice, the diameter of the orifice outlet, the viscosity of the fuel, and the injection pressure of the fuel. Increasing the ratio of the length of the orifice to its diameter will increase penetration and decrease atomization. Decreasing this ratio will have an opposite effect. Because penetration and atomization are opposed mutually and both are important, a compromise is necessary if uniform fuel distribution is to be obtained. The amount of fuel pressure for injection is dependent on the pressure of the air in the combustion chamber, and the amount of turbulence in the combustion space.

c. *Function of the Injection System.* It is impossible to cover the operation and construction of the many types of modern injection systems in this text. However, the operation of the more common systems will be discussed. If the three basic functions of diesel fuel injection are kept in mind while studying the operation of the systems, it will be easier to understand how they work. The three basic functions are:

(1) To meter the fuel accurately.

(2) To distribute the fuel equally to all of the cylinders at a high enough pressure to ensure atomization.

(3) To control the start, rate, and duration of the injection.

5-14. Multiple Unit Injection.

a. *General System Operation (Fig. 5-6).* The basic system consists of a fuel supply pump, fuel filter, multiple unit injection pump, and one injector for each cylinder. The operation of the system is as follows:

(1) The fuel supply pump and the fuel filter provide a low-pressure supply of fuel to the multiple unit injection pump. Pressure usually is regulated to approximately 15 psi (103.4 kPa).

(2) The multiple unit injection pump contains an individual injection pump for each engine cylinder. Fuel is delivered to the injectors at each cylinder from the multiple unit injection pump in a timed sequence and a regulated amount based on accelerator pedal position and engine speed.

(3) The injectors receive fuel charges from their respective injection pumps and spray it into the combustion chambers in a spray pattern that is tailored to provide the best overall performance for their particular application.

b. *The Multiple Unit Injection Pump (Fig. 5-7).*

(1) The multiple unit injection pump contains an individual plunger-type injector pump for each cylinder. These pumps are arranged in a line so that they may be driven by a common camshaft. The lobes of the camshaft are arranged so that they operate the injection pumps in a sequence that coincides with the firing order of the engine. This camshaft is driven by the engine through gears at a speed of exactly one-half that of the crankshaft. This exact speed is maintained so that the injectors will each deliver their fuel charge at the beginning of their respective cylinder's power stroke. Power strokes occur during every other crankshaft revolution in a four-stroke cycle diesel engine.

142

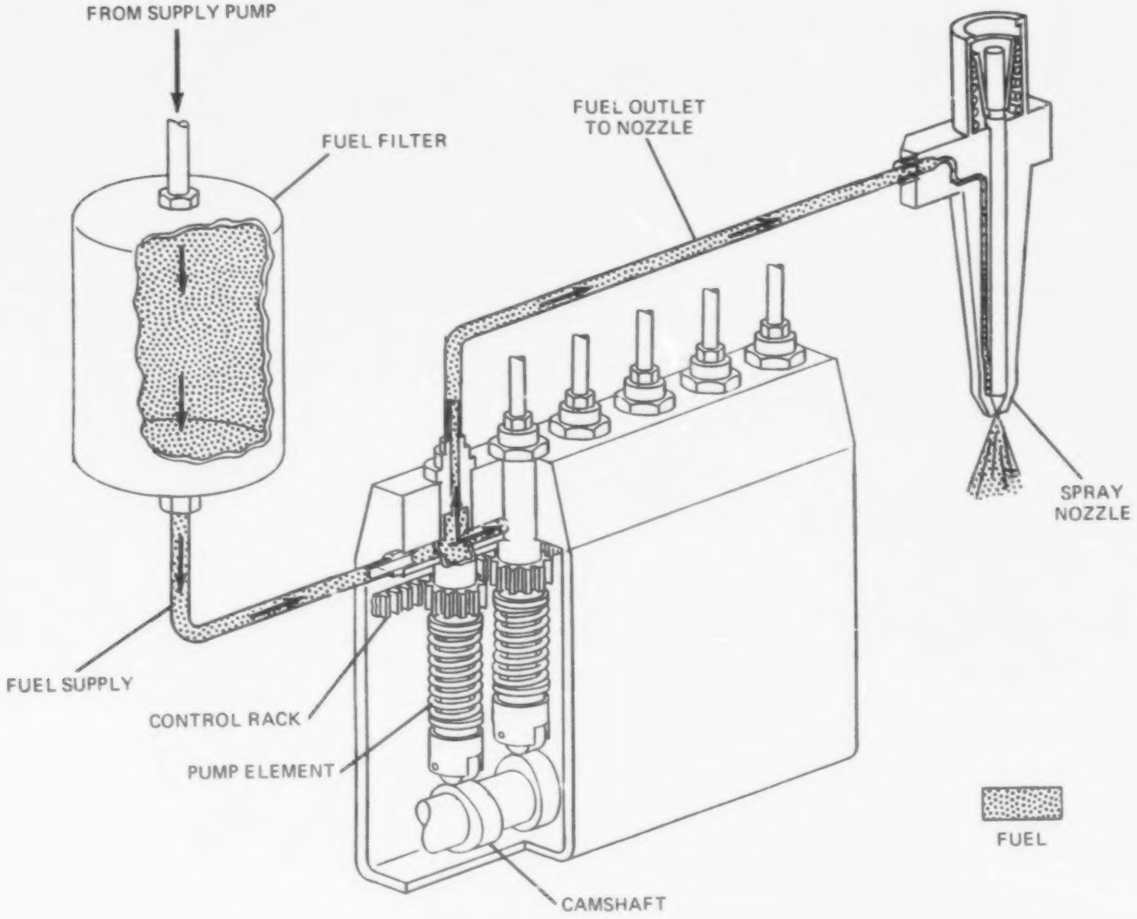


Figure 5-6. General System Operation.

(2) Excess fuel flows from the injection pump through the relief valve and back to the fuel tank. The relief valve usually is adjusted to open at approximately 15 psi (103.4 kPa).

(3) The pumps consist of a finely fitted plunger that is actuated by the camshaft against the force of the plunger spring. The bore that the plunger rides in has two passages machined into it. One of these passages is the delivery port, through which the pump is filled. The other passage is the spill port, through which excess fuel is discharged. When the plunger is fully in its return position, fuel flows into the pump cavity through the uncovered delivery port and out of the pump cavity through the uncovered spill port. The pump cavity always is kept full as the fuel flows through. The plunger moves up in its bore as it is actuated by the camshaft, sealing the ports. The fuel that is trapped in the cavity is forced out of the pump and to its respective injector.

(4) The pump plunger has a rectangular slot cut into it that leads from the top face, down the side, and finally connecting to a helical-shaped cavity that is called the bypass helix. In operation, the slot will allow fuel to pass to the bypass helix. As the bypass helix passes over the spill port, it will allow a portion of the fuel charge to bypass back to the fuel tank rather than being injected into the engine cylinder. The outer pump sleeve is made to rotate and has gear teeth around its outer diameter. A horizontal toothed rack meshes with these gear teeth to rotate the sleeve without any plunger rotation. By moving the rack back and forth, the outer pump sleeve is rotated, moving the delivery and spill ports in relation to the bypass helix on the pump plunger. This enables

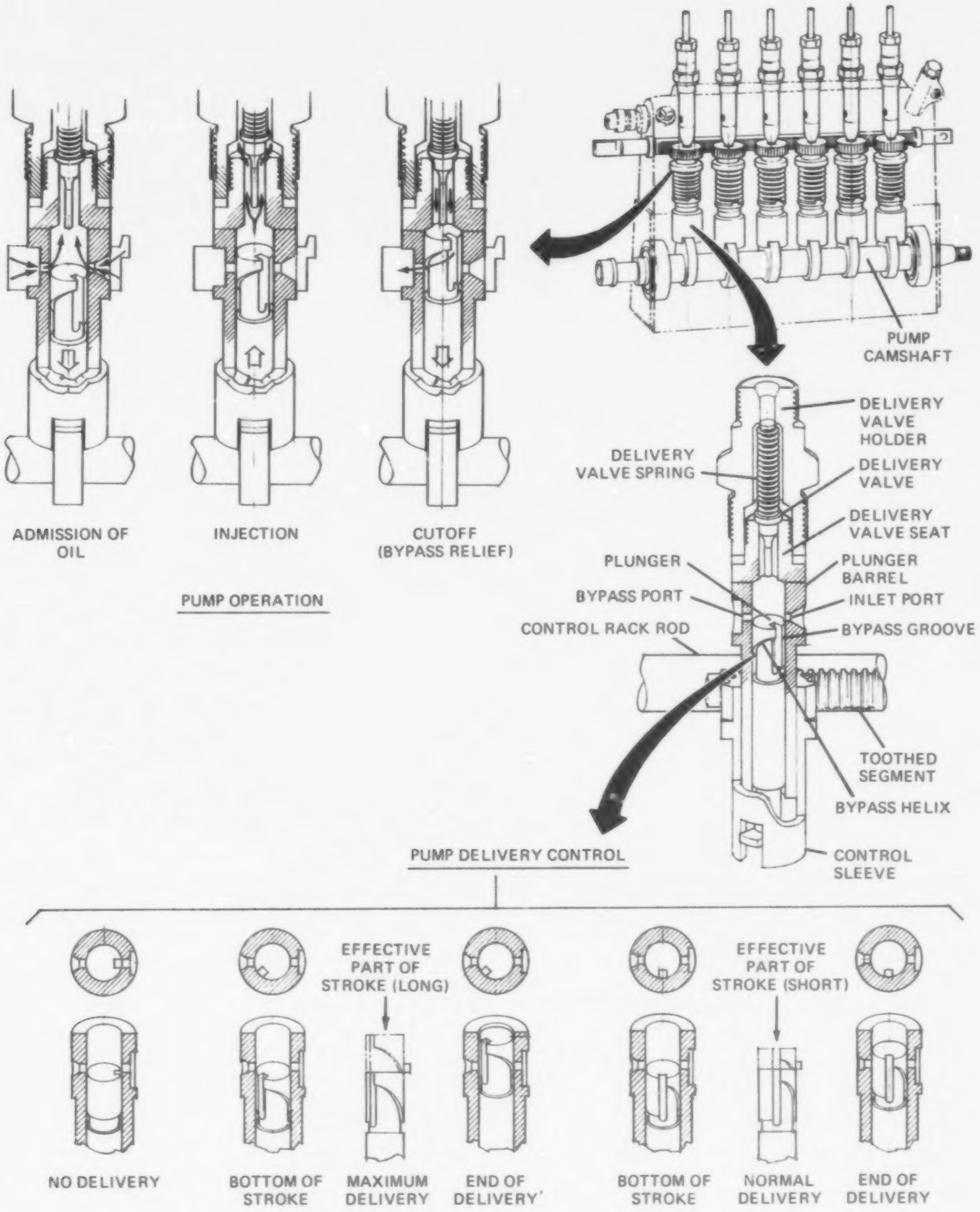

ADMISSION OF OIL
INJECTION
CUTOFF (BYPASS RELIEF)
PUMP OPERATION
PUMP CAMSHAFT
DELIVERY VALVE HOLDER
DELIVERY VALVE SPRING
DELIVERY VALVE
DELIVERY VALVE SEAT
PLUNGER
PLUNGER BARREL
BYPASS PORT
INLET PORT
CONTROL RACK ROD
BYPASS GROOVE
TOOTHED SEGMENT
BYPASS HELIX
PUMP DELIVERY CONTROL
CONTROL SLEEVE
EFFECTIVE PART OF STROKE (LONG)
EFFECTIVE PART OF STROKE (SHORT)
NO DELIVERY
BOTTOM OF STROKE
MAXIMUM DELIVERY
END OF DELIVERY
BOTTOM OF STROKE
NORMAL DELIVERY
END OF DELIVERY

Figure 5-7. Multiple Unit Injection Pump.

TA233444

the volume of fuel injected to the cylinders to be varied by changing the effective length of the pump stroke (the length of the pump stroke that occurs before the spill port is uncovered by the bypass helix). The rack extends down the whole row of injection pumps so that they are all operated simultaneously. The end result is that the injection pumps can be moved from full to no-fuel delivery by moving the rack back and forth. The movement of the rack is controlled by the governor (para 5-24).

(5) When the plunger begins its pump stroke it covers both ports. When this happens, the pressure exerted on the fuel causes the spring-loaded delivery valve to lift off of its seat, thereby permitting fuel to discharge into the tubing that leads to the spray nozzle. At the instant that the bypass helix uncovers the spill port, the fuel begins to bypass. This causes the pressure in the pump cavity to drop. The high pressure in the delivery line combined with spring pressure causes the delivery valve to close. When the delivery valve closes, it prevents fuel from the line from draining back into the pump, which could cause the system to lose its prime. As the delivery valve seats, it also serves to reduce pressure in the delivery line. The delivery valve has an accurately lapped displacement piston incorporated into it to accomplish pressure relief. The pressure is relieved in the line by the increase in volume as the delivery valve seats.

c. Fuel Injectors (Fig. 5-8). For proper engine performance, the fuel must be injected into the combustion space in a definite spray pattern. This is accomplished by the fuel injector.

(1) The fuel enters the nozzle holder body through the high-pressure inlet. It then passes

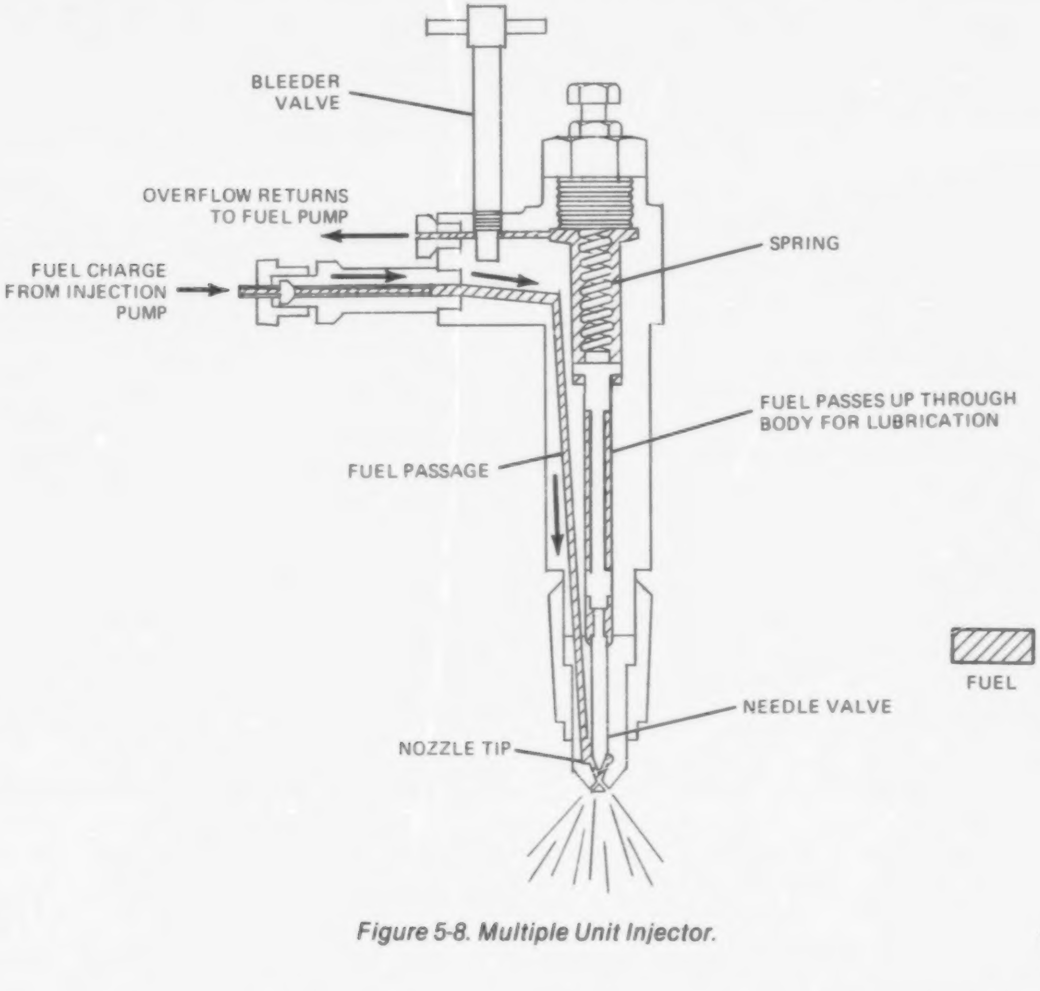

BLEEDER VALVE
OVERFLOW RETURNS TO FUEL PUMP
FUEL CHARGE FROM INJECTION PUMP
SPRING
FUEL PASSES UP THROUGH BODY FOR LUBRICATION
FUEL PASSAGE
▨ FUEL
NEEDLE VALVE
NOZZLE TIP

Figure 5-8. Multiple Unit Injector.

TA233445

down to the pressure chamber above the valve seat.

(2) At the moment that the pressure developed by the injection pump exceeds the force exerted by the pressure adjusting spring, the nozzle valve will be lifted off of its seat, resulting in the injection of fuel into the cylinder. The valve usually requires a fuel pressure of 1000 to 4000 psi (6895 to 27580 kPa) to open, depending on the engine combustion chamber requirements.

(3) A controlled seepage exists between the lapped surfaces of the nozzle valve and its body to provide for lubrication. The leakage or overflow passes around the spindle and into the pressure adjusting spring chamber. From here, the fuel leaves the injector through the overflow outlet and finally to the overflow lines, which lead back to the low-pressure fuel supply.

d. Injector Nozzles (Fig. 5-9). Because of the widely differing requirements in the shapes of the fuel spray for various chamber designs and the wide range of engine power demands, there is a large variety of injector nozzles in use. The spray nozzles are put into two basic groups: pintle nozzles and hole nozzles. Pintle nozzles generally are used in engines having precombustion or turbulence chambers, whereas the hole nozzles generally are used in open chamber engines.

(1) In pintle nozzles, the nozzle valve carries an extension at its lower end in the form of a pin (pintle), which protrudes through the hole in the nozzle bottom. This requires the injected fuel to pass through an annular orifice, producing a hollow, cone-shaped spray, the nominal included angle of which may be from 0 to 60 degrees, depending on the combustion chamber requirement. The projection of the pintle through the nozzle orifice includes a self-cleaning effect, discouraging the accumulation of carbon at this point.

(2) A specific type of pintle nozzle that is used extensively in small bore high-speed diesel engines is the throttling nozzle. It differs from the standard pintle nozzle in that the pintle projects from the nozzle for a much greater distance, and the orifice in the bottom of the nozzle body is much longer. The outstanding feature of the throttling nozzle is its control of the rate at which fuel is injected into the combustion chamber. When no fuel is being injected, the pintle extends through the nozzle orifice. At the beginning of the injection period, only a small quantity of fuel is injected into the chamber because the straight section of the pintle is in the nozzle orifice. The volume of the fuel spray then increases progressively as the pintle is lifted higher, because the straight section leaves the nozzle orifice and the tapered tip of the pintle in the orifice provides a larger opening for the flow of fuel.

(3) Another type of throttling nozzle has its pintle flush with the nozzle-body tip for no-fuel delivery and extended through the body for maximum fuel delivery. In this type, fuel under high pressure from the injection pump acts on the seat area of the pintle, forcing it outward against a preloaded spring. This spring, through its action on a spring hanger, also returns the pintle to its seat, sealing the nozzle against further injections or dribble when the line pressure is relieved at the pump. When the pintle moves outward due to fuel pressure, an increasingly larger orifice area is opened around the flow angle of the pintle.

(4) The hole nozzles have no pintle but basically are similar in construction to the pintle type. They have one or more spray orifices that are straight, round passages through the tip of the nozzle body beneath the valve seat. The spray from each orifice is relatively dense and compact, and the general spray pattern is determined by the number and the arrangement of the holes. As many as 18 holes are provided in larger nozzles, and the diameter of these drilled orifices may be as small as 0.006 in. (0.152 mm). The spray pattern may not be symmetrical, as in the case of the multifuel engine, where the spray pattern is off to one side so as to deposit the fuel properly in the spherical combustion chamber (para 5-12). The size of the holes determines the degree of atomization attained. The smaller the holes, the greater the atomization; but if the hole is too small, it will be impossible to get enough fuel into the chamber during the short time allowed for injection. If the hole is too large, there will be an overrich mixture near the nozzle tip and a lean mixture at a distance from it. Using multiple holes in the injector tips usually overcomes both difficulties because the holes can be drilled small enough to provide proper atomization and a sufficient number can be provided to allow the proper amount of fuel to enter during the injection period.

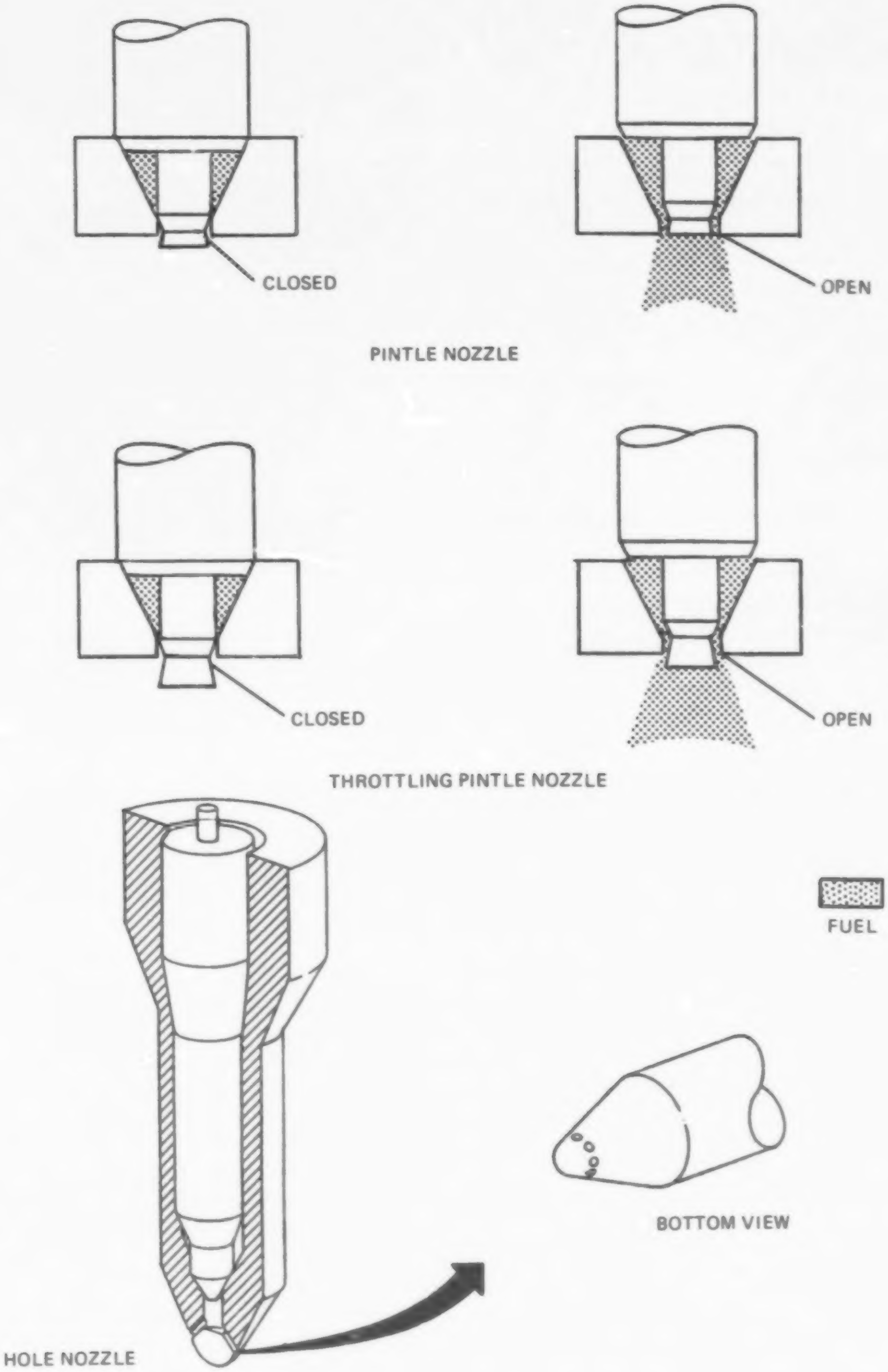

CLOSED
OPEN
PINTLE NOZZLE
CLOSED
OPEN
THROTTLING PINTLE NOZZLE
FUEL
BOTTOM VIEW
HOLE NOZZLE

Figure 5-9. Injector Nozzles.

TA233446

5-15. Wobble Plate Pump System (Fig. 5-10).

a. General System Operation. The wobble plate pump system basically is the same as the multiple unit injection system (para 5-14). The difference in the system lies in the injection pump. In a wobble plate pump, all of the pump plungers are actuated by a single wobble plate instead of a camshaft that has a separate cam for each pump plunger. Also, the metering of the fuel is accomplished by a single axially located rotary valve in the wobble plate unit, whereas the rotary movement of the individual plungers controls the amount of fuel in the multiple unit injection pump.

b. Wobble Plate Pump Principles. A plate is mounted on a shaft and set at an angle to it so that as the shaft rotates, the plate moves laterally in relation to any given point on either side of it. The pump derives its name from the fact that the plate appears to wobble back and forth as it rotates. The end of the push rod is placed in a guide plate that lays against the wobble plate. The push rod is held in a bore in the pump body so that is can move only in a direction parallel to the wobble plate shaft. The rotation of the wobble plate then causes the guide plate to wobble, thus moving the push rod back and forth. The push rod is connected to the pump plunger so that movement to the left actuates the pump on its delivery stroke and a spring returns it on the suction stroke.

c. The Wobble Plate Injection Pump. As stated previously, the wobble plate injection pump contains an individual plunger-type pump for each cylinder. The pump plungers are spaced equally about the wobble plate. As the wobble plate rotates, it will actuate all of the individual injection pumps. At any given time during rotation, half of the plungers will be moving on their delivery stroke while the other half will be on their return stroke.

(1) The rotary metering valve is driven by the same shaft that drives the wobble plate. The rotary valve consists of a lapped cylindrical shaft that is fitted closely in a barrel to prevent fuel from escaping at its ends. Fuel is admitted to the barrel at the center of the valve, which contains a spoollike reduction in diameter. This reduction in diameter acts as a fuel reservoir.

(2) The reduced portion of the valve is in the shape of a band broken by a triangular land that is the same diameter as the ends of the valve. The reservoir created by the reduced portion of the valve is connected to each pump cavity by individual ports so that the pump cavities may be supplied with fuel. This reservoir receives a constant supply of low-pressure fuel from the delivery pump. As with the multiple unit injection system, delivery pump pressure is regulated to approximately 15 psi (103.43 kPa).

(3) The triangular land serves to consecutively block each pump delivery port as it rotates. The triangular land is situated so that it will block each pump delivery port at the same time that the wobble plate is moving the respective pump plunger at the maximum speed through its delivery stroke. Fuel is delivered to the fuel injector as long as the delivery port is blocked.

(4) The rotational relationship of the rotary valve and the wobble plate causes each pump to deliver a fuel charge to its respective injector in turn as the pump rotates. The pumps in the injection unit are connected to the fuel injectors to coincide with the firing order of the engine. The pump is gear driven by the engine at a speed of exactly one-half that of the crankshaft. The end result will be the injection of fuel to each cylinder at the beginning of each power stroke.

(5) To obtain zero delivery, the valve is moved endwise to a position where the delivery ports are never blocked by the triangular land. When this occurs, the movement of the pump plungers merely causes the fuel to move back and forth in the delivery ports. This results in zero delivery to the injectors due to insufficient pressure to open the spring-loaded delivery valves.

(6) To cause the pump to deliver fuel, the rotary valve is moved endwise so that the triangular land begins to block the delivery ports. Due to the triangular shape of the land, further endwise movement of the rotary valve will increase the time that the port is blocked, increasing fuel delivery. The end result is that fuel delivery can be controlled by the endwise movement of the rotary valve. Endwise movement of the rotary valve is accomplished by the control lever. The position of the control lever is determined by the governor (para 5-24).

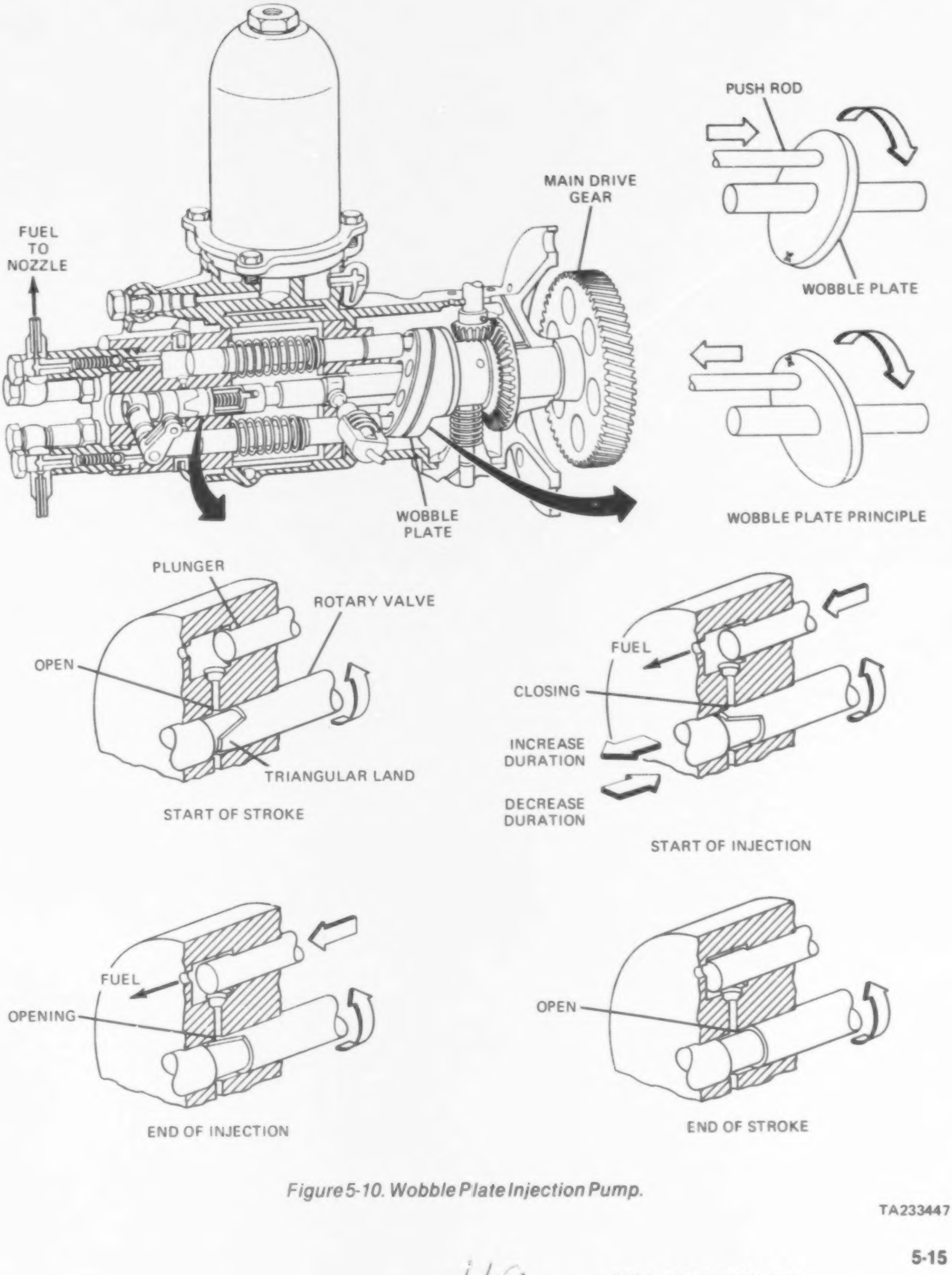

PUSH ROD
MAIN DRIVE GEAR
FUEL TO NOZZLE
WOBBLE PLATE
WOBBLE PLATE
WOBBLE PLATE PRINCIPLE
PLUNGER
ROTARY VALVE
OPEN
TRIANGULAR LAND
START OF STROKE
FUEL
CLOSING
INCREASE DURATION
DECREASE DURATION
START OF INJECTION
FUEL
OPENING
END OF INJECTION
OPEN
END OF STROKE

Figure 5-10. Wobble Plate Injection Pump.

TA233447

5-16. Distributor-Type Injection System.

a. General System Operation (Fig. 5-11). The distributor injection system used in automotive diesel engines is classed as a low-pressure system in that pumping, metering, and distribution operations take place at low pressure. The high pressure required for injection is built up by the injector at each cylinder. A suction pump lifts fuel from the tank and delivers it to the float chamber. From here a second low-pressure pump delivers the fuel to the distributor. Fuel passes through the distributor to the metering pump, where it is divided into measured charges. The fuel charges then are delivered back to the distributor, where they are sent to the injectors in the proper sequence. The measured charges then are sprayed into the engine cylinders at the proper time and under high pressure by the fuel injectors.

b. Distributor. The distributor consists of a rotating disk and a stationary cover to which the fuel lines to the individual injectors are connected. The disk and the cover have a series of holes that, when properly indexed, form passages from the fuel supply pump to the metering pump. The disk is timed so that this occurs when the metering plunger is moving down on its suction stroke, thus permitting the metering pump to be filled with oil. As the disk continues to rotate, it lines up with the correct discharge hole in the cover just as the metering plunger begins its delivery stroke, forcing the fuel into the proper injector line. As it continutes to rotate, the disk works in the same timed sequence in conjunction with the metering pump to feed fuel to the remaining cylinders. The rotating disk turns at one-half crankshaft speed because power strokes occur every other crankshaft revolution in a four-stroke cycle diesel engine.

c. Metering Unit (Fig. 5-12). The metering unit is a closely fitted reciprocating pump, obtaining its motion through a link from the plunger lever. The plunger lever is operated by a vertical lever, controlled in turn by an eccentric rocker lever running directly off a cam on the fuel pump main shaft. The position of the vertical lever in the eccentric of the rocker lever determines the travel of the plunger lever and, in turn, the travel of the metering pump plunger. As the pump plunger starts upward on its controlled stroke, it pushes fuel to the injector through passages formed by the rotating distributor disk. The stroke of the metering plunger, which determines the amount of fuel going to each injector, is varied by changing the position of the plunger lever between the stop pins in the cam rocker lever. The position of the plunger lever is adjusted by the governor (para 5-25) through the control lever.

d. Injectors (Fig. 5-13). The injector consists of a forged body with a properly fitted plunger. This plunger is forced down against spring action by the engine camshaft through a rocker arm and push rod. There is a fuel cup mounted on the end of the body combined with a hole-type nozzle (para 5-14).

(1) The fuel metering pump forces a precisely measured fuel charge into the cup on the intake stroke of the engine. The quantity of the fuel charge is based on the speed and load requirements of the engine. The operation of this system depends on the injector delivery line being full of fuel. Then it will naturally follow that any fuel added by the fuel metering pump will discharge an equal amount of fuel at the other end of the line into the injector.

(2) The fuel lies in the cup during the compression stroke of the engine, and the compressed air is forced through the small spray holes in the cup. The fuel in the tip of the cup is exposed to the intense heat of compression. The turbulence caused by the air rushing in through the holes in the nozzle tip serves to break the fuel charge into droplets.

(3) A few degrees before top dead center, at the beginning of the power stroke, the injector plunger is forced down, causing the fuel charge to be sprayed out of the cup, through the nozzle holes, and into the combustion chamber. The downward movement of the injector plunger is spread out through the entire power stroke.

(4) There is a small check valve located in the inlet passage of the injector body. Its purpose is to allow fuel to enter the injector cup but block high combustion chamber pressure from blowing air into injector delivery lines.

5-17. Unit Injection System (Fig. 5-14).

a. Overall System Operation. The unit injection system operates in the same manner as the

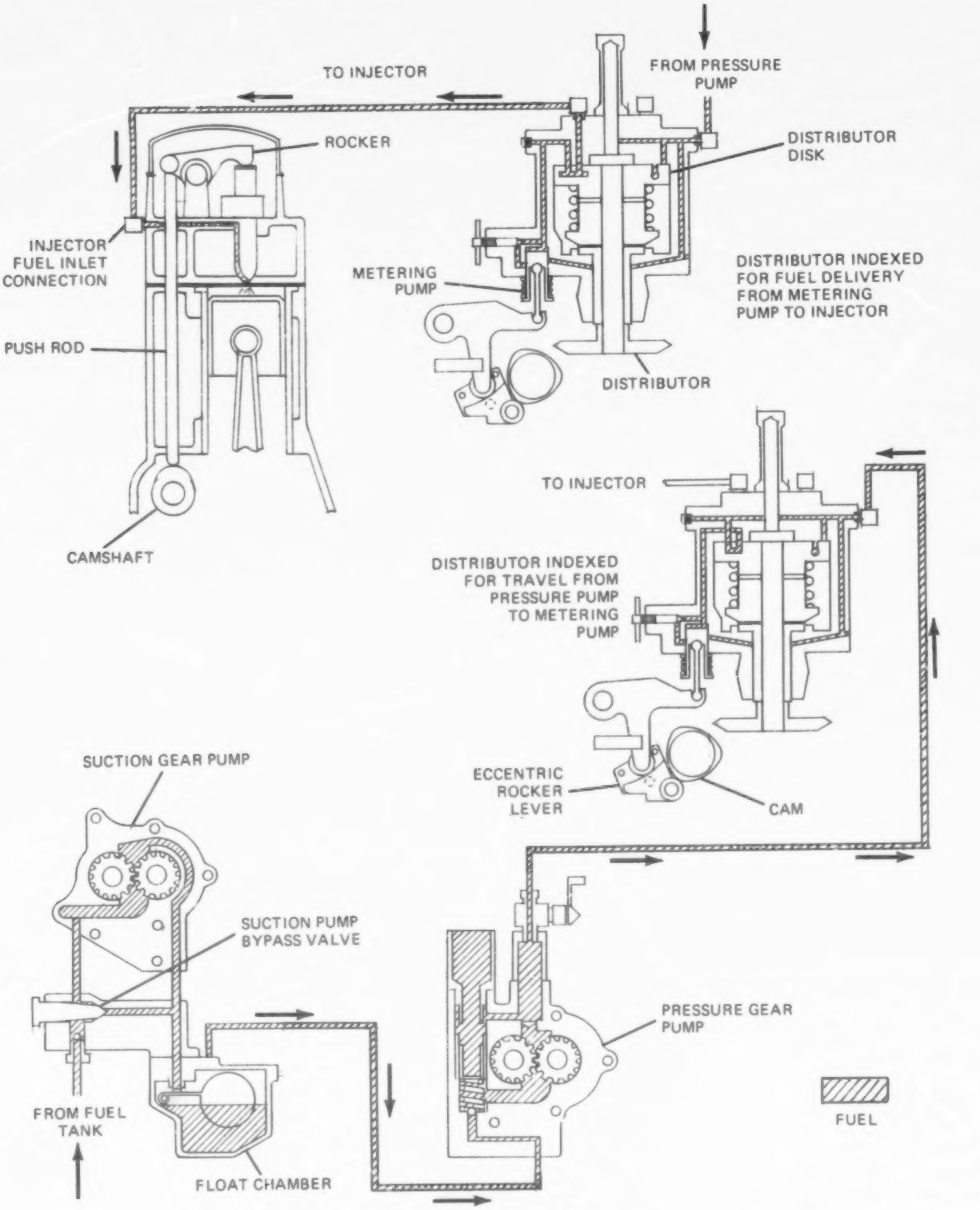

TO INJECTOR
FROM PRESSURE PUMP
ROCKER
DISTRIBUTOR DISK
INJECTOR FUEL INLET CONNECTION
METERING PUMP
DISTRIBUTOR INDEXED FOR FUEL DELIVERY FROM METERING PUMP TO INJECTOR
PUSH ROD
DISTRIBUTOR
TO INJECTOR
CAMSHAFT
DISTRIBUTOR INDEXED FOR TRAVEL FROM PRESSURE PUMP TO METERING PUMP
SUCTION GEAR PUMP
ECCENTRIC ROCKER LEVER
CAM
SUCTION PUMP BYPASS VALVE
PRESSURE GEAR PUMP
▨
FUEL
FROM FUEL TANK
FLOAT CHAMBER

Figure 5-11. Distributor Injection System.

TA233448

151

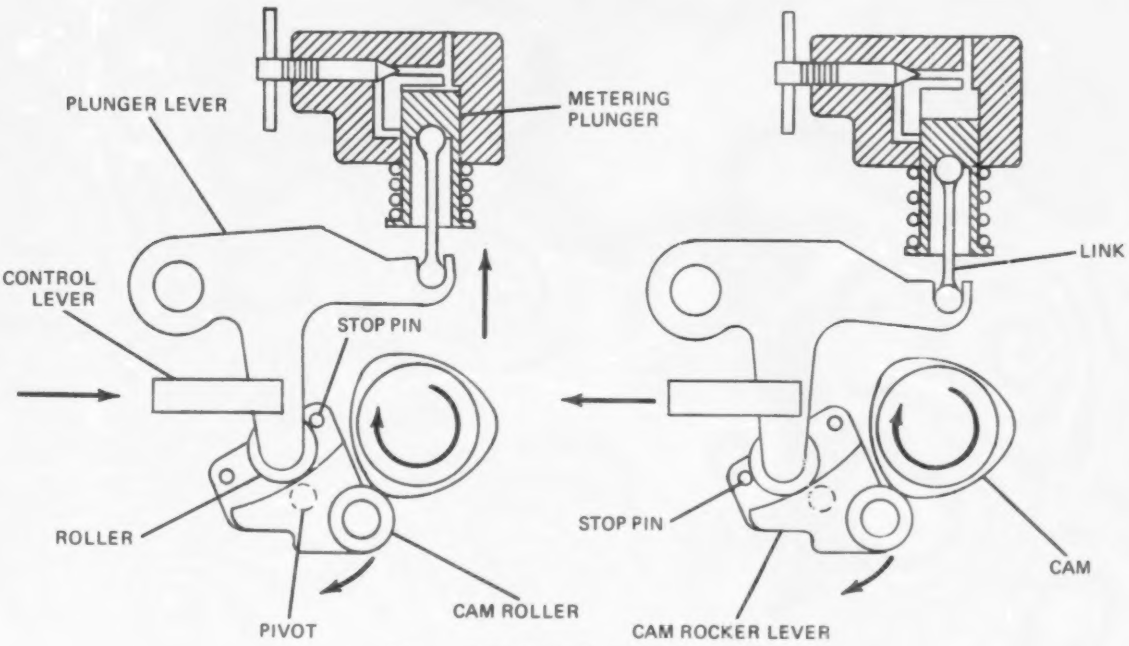

PLUNGER LEVER
METERING PLUNGER
CONTROL LEVER
STOP PIN
LINK
ROLLER
STOP PIN
CAM
PIVOT
CAM ROLLER
CAM ROCKER LEVER

Figure 5-12. Fuel Metering System.

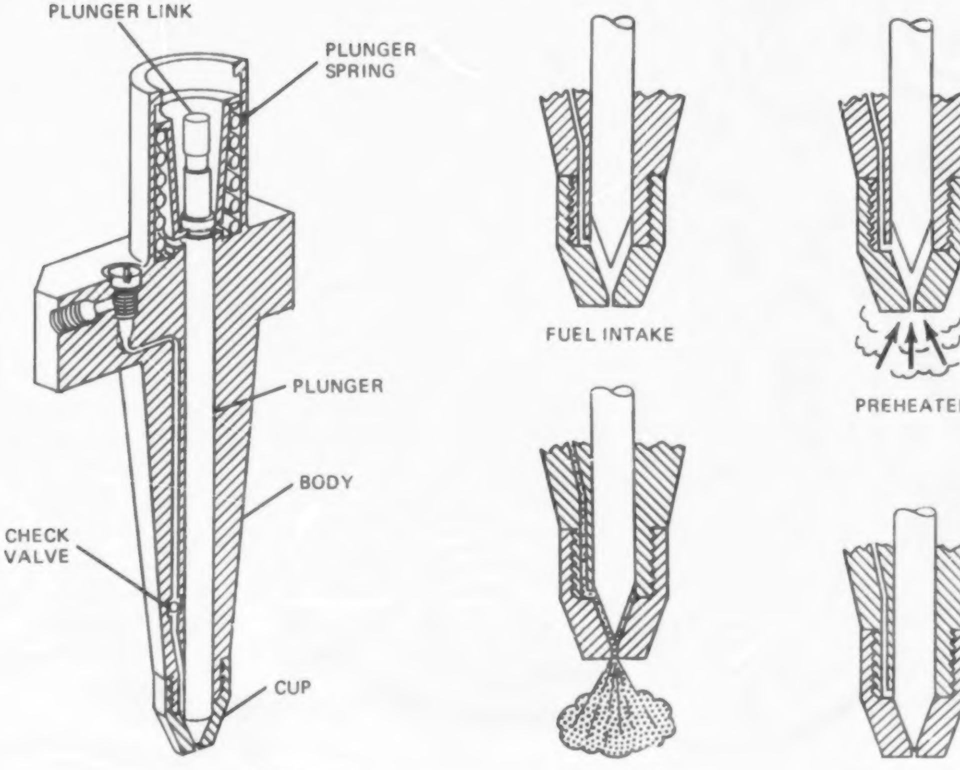

PLUNGER LINK
PLUNGER SPRING
PLUNGER
BODY
CHECK VALVE
CUP
FUEL
FUEL INTAKE
PREHEATED
INJECTION
END OF STROKE
TA233449

Figure 5-13. Distributor-Type Unit Injectors.

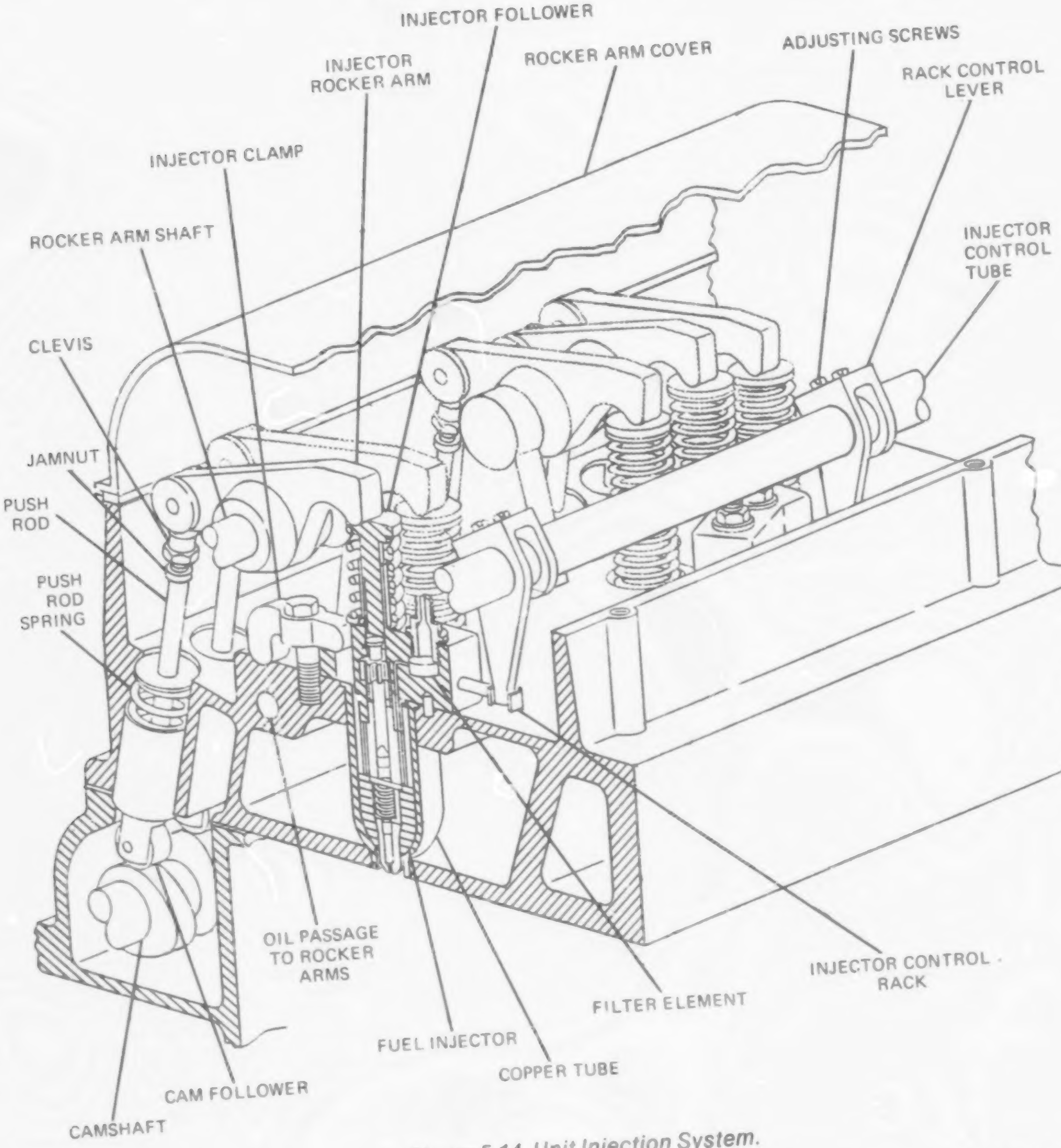

INJECTOR FOLLOWER
INJECTOR ROCKER ARM
ROCKER ARM COVER
ADJUSTING SCREWS
RACK CONTROL LEVER
INJECTOR CLAMP
ROCKER ARM SHAFT
INJECTOR CONTROL TUBE
CLEVIS
JAMNUT
PUSH ROD
PUSH ROD SPRING
OIL PASSAGE TO ROCKER ARMS
INJECTOR CONTROL RACK
FILTER ELEMENT
FUEL INJECTOR
COPPER TUBE
CAM FOLLOWER
CAMSHAFT

Figure 5-14. Unit Injection System.

multiple unit injection system (para 5-14). The difference is that rather than using a centrally located unit to house the high-pressure pumps, control racks, pressure regulators, and delivery valves, they are all incorporated into each injector. This eliminates the need for high-pressure lines or any other apparatus besides the fuel supply pump.

b. *Fuel Supply.* Fuel is drawn from the fuel tank by the fuel supply pump, through the primary fuel filter, and directly to the individual injector units. The fuel is supplied at low pressure, approximately 20 psi (137.9 kPa).

c. *Injector Units (Fig. 5-15).* Unit injectors combine the injection pump, the fuel valves, and the nozzle in a single housing. These units provide a complete and independent injection system for each cylinder. The units are mounted

TA233450

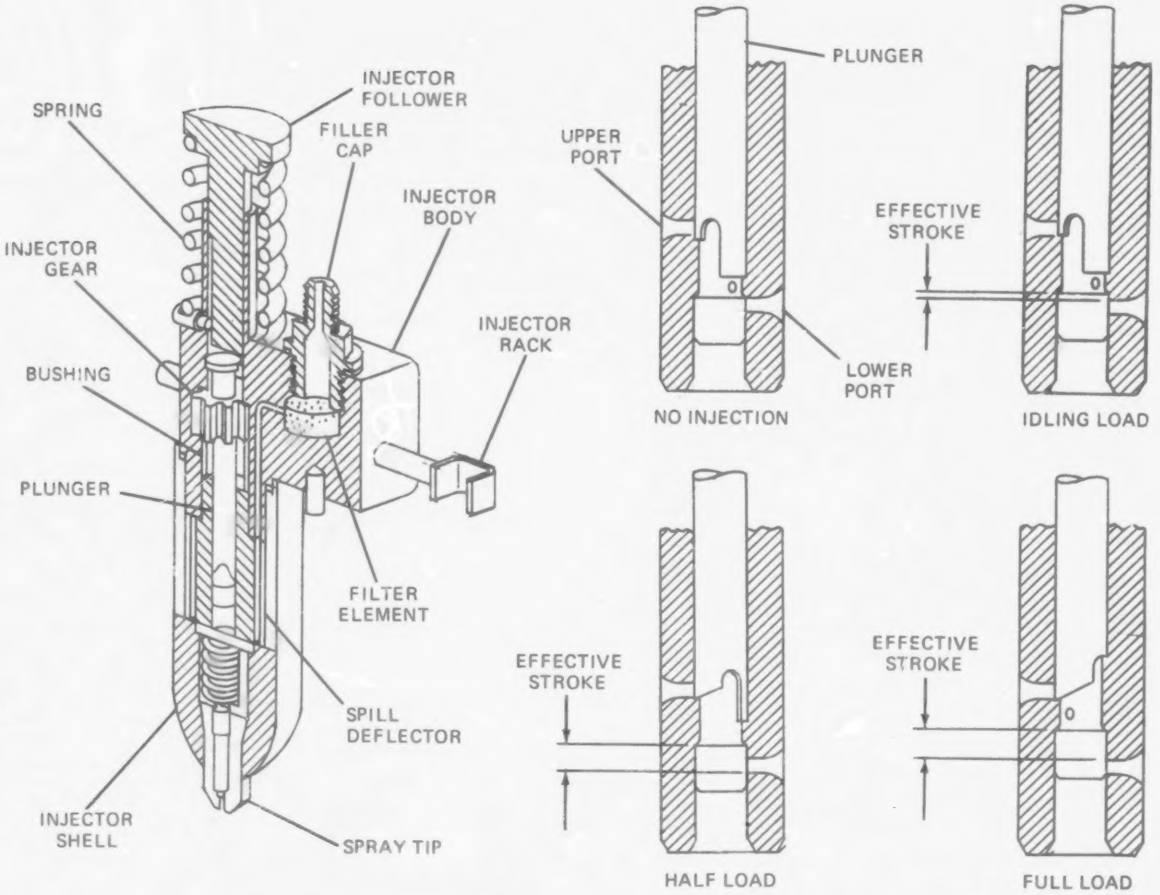

SPRING
INJECTOR FOLLOWER
FILLER CAP
INJECTOR BODY
INJECTOR GEAR
INJECTOR RACK
BUSHING
PLUNGER
FILTER ELEMENT
SPILL DEFLECTOR
INJECTOR SHELL
SPRAY TIP
PLUNGER
UPPER PORT
EFFECTIVE STROKE
LOWER PORT
NO INJECTION
IDLING LOAD
EFFECTIVE STROKE
EFFECTIVE STROKE
HALF LOAD
FULL LOAD

Figure 5-15. Unit Injector Operation.

in the cylinder head with their spray nozzles protruding into the combustion chamber. A clamp, bolted to the cylinder head and fitting into a machined recess in each side of the injector, holds the injector in place in a water-cooled copper tube that passes through the cylinder head. The tapered lower end of the injector seats in the copper tube, forming a tight seal to withstand the high pressures inside the cylinder. The injector operates as follows:

(1) Fuel is supplied to the injector through the filter cap. After passing through the fine-grained filter element in the inlet passage, the fuel fills the annular-shaped supply chamber that is created between the bushing and the spill deflector.

(2) The bushing bore is connected to the fuel supply by two funnel-shaped ports, one on each side at different heights. The plunger operates up and down in the bushing bore.

(3) The plunger is actuated by a camshaft that is built right into the engine. The operation takes place through a rocker arm and a push rod. The push rod has a roller-type cam follower and is spring loaded to prevent component damage in the event of injector nozzle clogging. The plunger is situated under a follower. This follower is spring loaded to make it follow the camshaft.

(4) The plunger can be rotated in operation around its axis by the gear, which is meshed to the control rack. Each injector rack is connected by an easily detachable joint to a lever on a common control tube which, in turn, is linked to the governor and the throttle.

TA233451

(5) For metering purposes, a recess with an upper helix and a lower helix or a straight cutoff is machined into the lower end of the plunger. The relation of this upper helix and lower cutoff to the two ports changes with the rotation of the plunger. As the plunger moves downward, the fuel in the high-pressure cylinder or bushing is first displaced through the ports back into the supply chamber until the lower edge of the plunger closes the lower port. The remaining oil is then forced upward through the center passage in the plunger into the recess between the upper helix and the lower cutoff, from which it can flow back into the supply chamber until the helix closes the upper port. The rotation of the plunger, by movement of the rack, changes the position of the helix in relation to the ports. This will advance or retard the closing of the ports and the beginning and ending of the injection period. This will result in a regulation of the volume of the fuel charge that is injected into the cylinder.

(6) When the control rack is pulled out completely, the upper port is not closed by the helix until after the lower port is uncovered. This means that all the fuel in the high-pressure cylinder bypasses back to the fuel supply and no fuel is injected into the combustion chamber.

(7) When the control rack is pushed in fully, the upper port is closed shortly after the lower port has been covered, thus producing a full effective stroke and maximum injection.

(8) From the no-delivery to the full-delivery positions of the control rack, the contour of the helix advances the closing of the ports and the beginning of injection.

(9) On the downward travel of the plunger, the metered amount of fuel is forced through the center passage of the valve assembly, through the check valve, and against the spray tip valve. When sufficient fuel pressure is built up, the spray tip valve is forced off of its seat and fuel is discharged through the hole-type injector nozzle (para 5-14). The check valve prevents air leakage from the combustion chamber into the fuel system in the event that the spray tip valve does not seat properly.

(10) On the return upward movement of the plunger, the high-pressure cylinder is again filled with oil through the ports. The constant circulation of fuel through the injectors back through the return helps to maintain an even operating temperature in the injector, which would otherwise tend to run very hot due to extreme pressures. Constant circulation also helps to remove all traces of air from the system. The amount of fuel circulated through the injector is in excess of maximum needs, thus ensuring sufficient fuel for all conditions.

5-18. Pressure-Timed (PT) Injection System.

a. Overall System Operation (Fig. 5-16). The pressure-timed injection system has a metering system that is based on the principle that the volume of liquid flow is proportional to the fluid pressure, the time allowed to flow, and the size of the passage the liquid flows through. The operation of the system is as follows:

(1) A fuel tank with a vented filler cap stores the fuel supply.

(2) Fuel is supplied from the tank to the pressure-timed gear (PTG) pump through the delivery line. An in-line filter is placed in series in the line to trap foreign matter and moisture.

(3) A return line from the PTG pump to the fuel tank is provided to bleed off excess fuel so that operating pressures can be regulated.

(4) The PTG pump (para 5-18b) delivers controlled amounts of fuel to the pressure-timed delivery (PTD) injectors.

(5) Delivery of fuel to the PTD injectors is through a common-rail type delivery line.

(6) A common-rail type return line connects the PTD injectors to the fuel tank so that excess fuel may be diverted back to the fuel tank.

b. PTG Injection Pump (Fig. 5-17). The PTG pump is driven directly by the engine at a one-to-one speed ratio. The pump contains four main components. These four components and their respective operations are as follows:

(1) The gear-type pump (para 5-23) draws fuel from the supply tanks and forces it through the pump filter screen to the governor. It is driven by the pump main shaft and picks up and delivers fuel

155

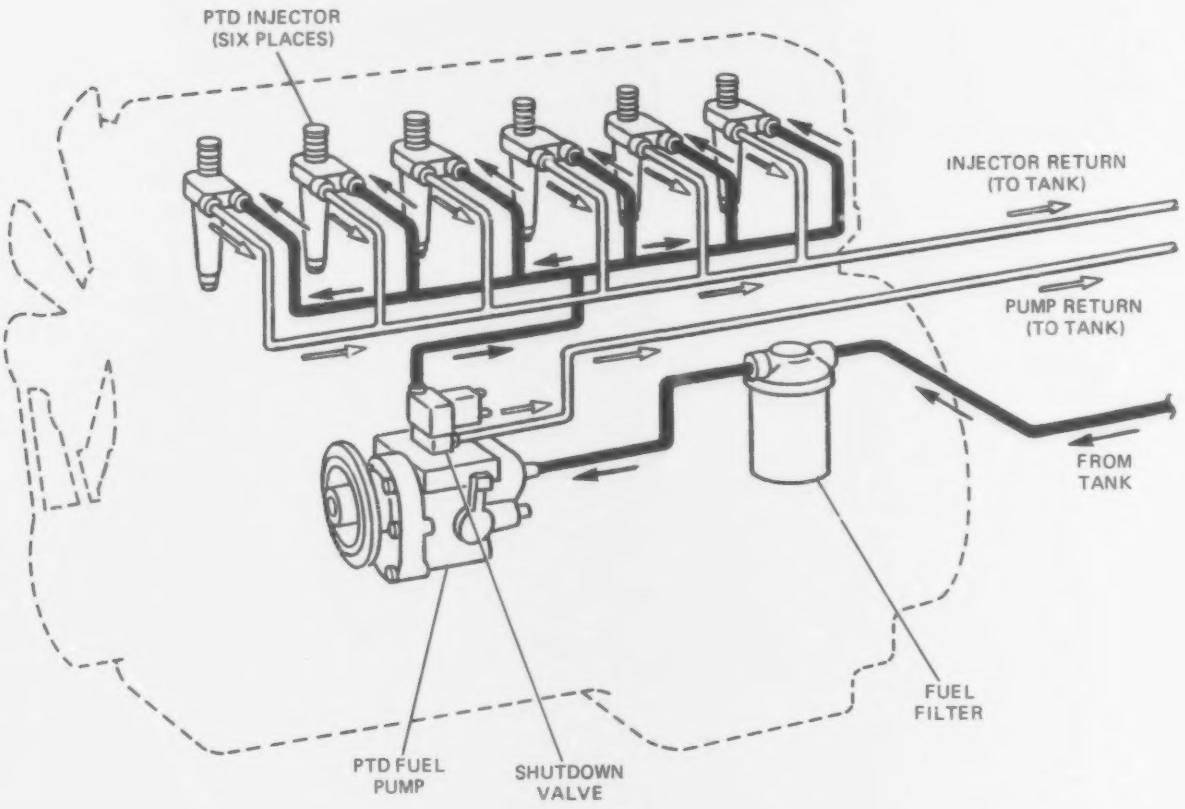


Figure 5-16. Pressure-Timed Injection System.

throughout the fuel system. A pulsation damper mounted to the gear pump contains a steel diaphragm that absorbs pulsations and smooths fuel flow through the fuel system. From the gear pump, fuel flows through the filter screen to the governor screen. The PTG pumps are equipped with a bleed line that is attached to the engine injector return line or to the tank. This prevents excessive fuel temperature within the fuel pump by using the surplus fuel as a coolant. The bleed line functions primarily when the pump throttle is set at idle speed, but gear pump output is high due to engine operating speed, as occurs during downhill operation. A special check valve and/or fitting is used in the gear pump to accomplish the bleed action.

(2) The governor controls the flow of the fuel from the gear pump, as well as the maximum and idle speeds. The mechanical governor is actuated by a system of springs and weights and has two functions: First, the governor maintains sufficient fuel for idling with the throttle control in idle position; second, it will restrict fuel to the injectors above maximum rated rpm. The idle springs (in the governor spring pack) position the governor plunger so the idle fuel port is opened enough to permit passage of fuel to maintain engine idle speed. During operation between idle and maximum speeds, fuel flows through the governor to the injector in accordance with the engine requirements, as controlled by the throttle and limited by the size of the idle spring plunger counterbore on the PTG fuel pumps. When the engine reaches governed speed, the governor weights move the governor plunger, and fuel flow to the injectors is restricted. At the same time, another passage opens and dumps the fuel back into the main pump body. In this manner, engine speed is controlled and limited by the governor, regardless of throttle position. Fuel leaving the pump flows through the shutdown valve, inlet supply lines, and into the injectors.

(3) The throttle provides a means for the

TA233452

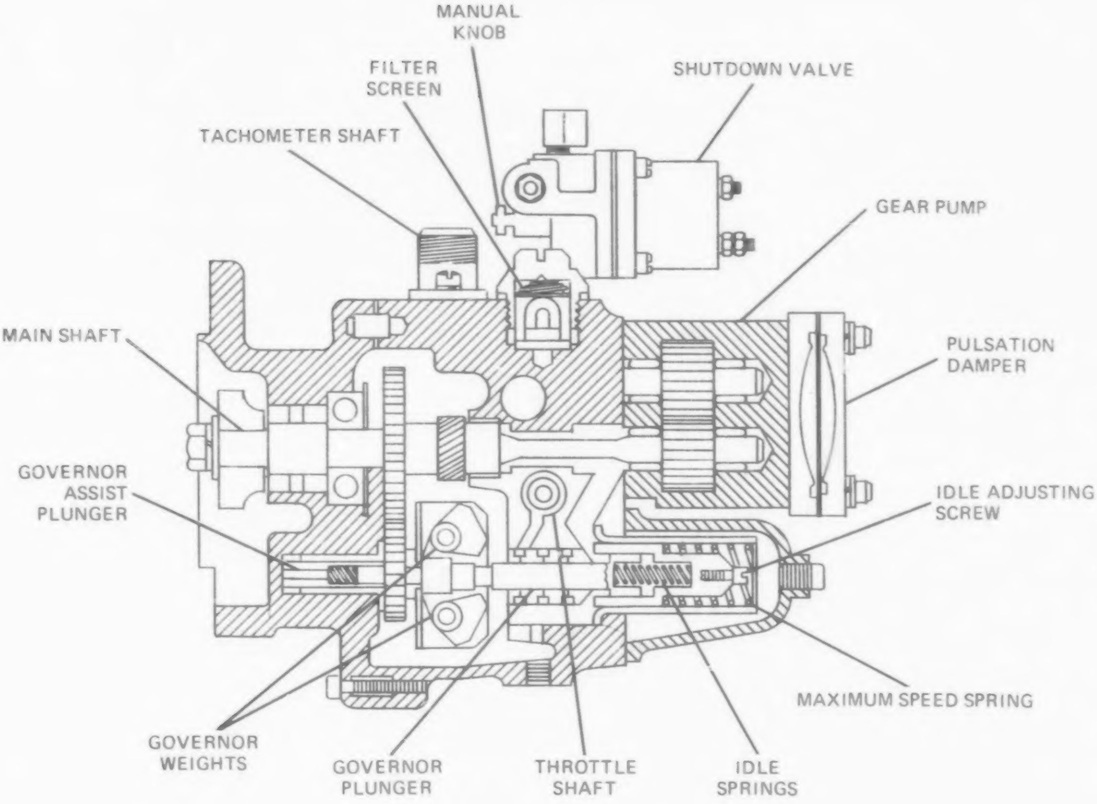

MANUAL KNOB
FILTER SCREEN
SHUTDOWN VALVE
TACHOMETER SHAFT
GEAR PUMP
MAIN SHAFT
PULSATION DAMPER
GOVERNOR ASSIST PLUNGER
IDLE ADJUSTING SCREW
MAXIMUM SPEED SPRING
GOVERNOR WEIGHTS
GOVERNOR PLUNGER
THROTTLE SHAFT
IDLE SPRINGS

Figure 5-17. Pressure-Timed Gear Pump.

operator to manually control engine speed above idle as required by varying operating conditions of speed and load. In the PTG pump, fuel flows through the governor to the throttle shaft. At idle speed, fuel flows through the idle port in the governor barrel, past the throttle shaft. To operate above idle speed, fuel flows through the main governor barrel port to the throttling hole in the shaft.

(4) The fuel shutdown valve is located on top of the fuel pump. It shuts off fuel to the injectors. With the master switch on, the solenoid opens the valve. With the switch off, the spring-loaded valve returns to the OFF position. In case of an electrical failure, rotation of the manual knob clockwise will permit fuel to flow through the valve. The knob is located on the front of the valve.

c. *PTD Injectors.* A PTD injector is provided at each engine cylinder to spray the fuel into the combustion chambers. PTD injectors are of the unit type, operated by an engine-based camshaft. Fuel flows from a connection at the top of the fuel pump shutdown valve through a supply line into the lower drilled passage in the cylinder head at the front of the engine. A second drilling in the head is alined with the upper injector radial groove to drain away excess fuel. A fuel drain at the flywheel end of the engine allows return of the unused fuel to the fuel tank. There are four phases of injector operation:

(1) *Metering (A, Fig. 5-18).* This phase begins with the plunger just beginning to move downward and the engine is on the beginning of the compression stroke. The fuel is trapped in the cup, the check ball stops the fuel from flowing backwards, and the fuel begins to be pressurized. The excess fuel flows around the lower annular ring, up the barrel, and is trapped there.

(2) *Preinjection (B, Fig. 5-18).* The plunger is almost all the way down, the engine is

TA233453

157

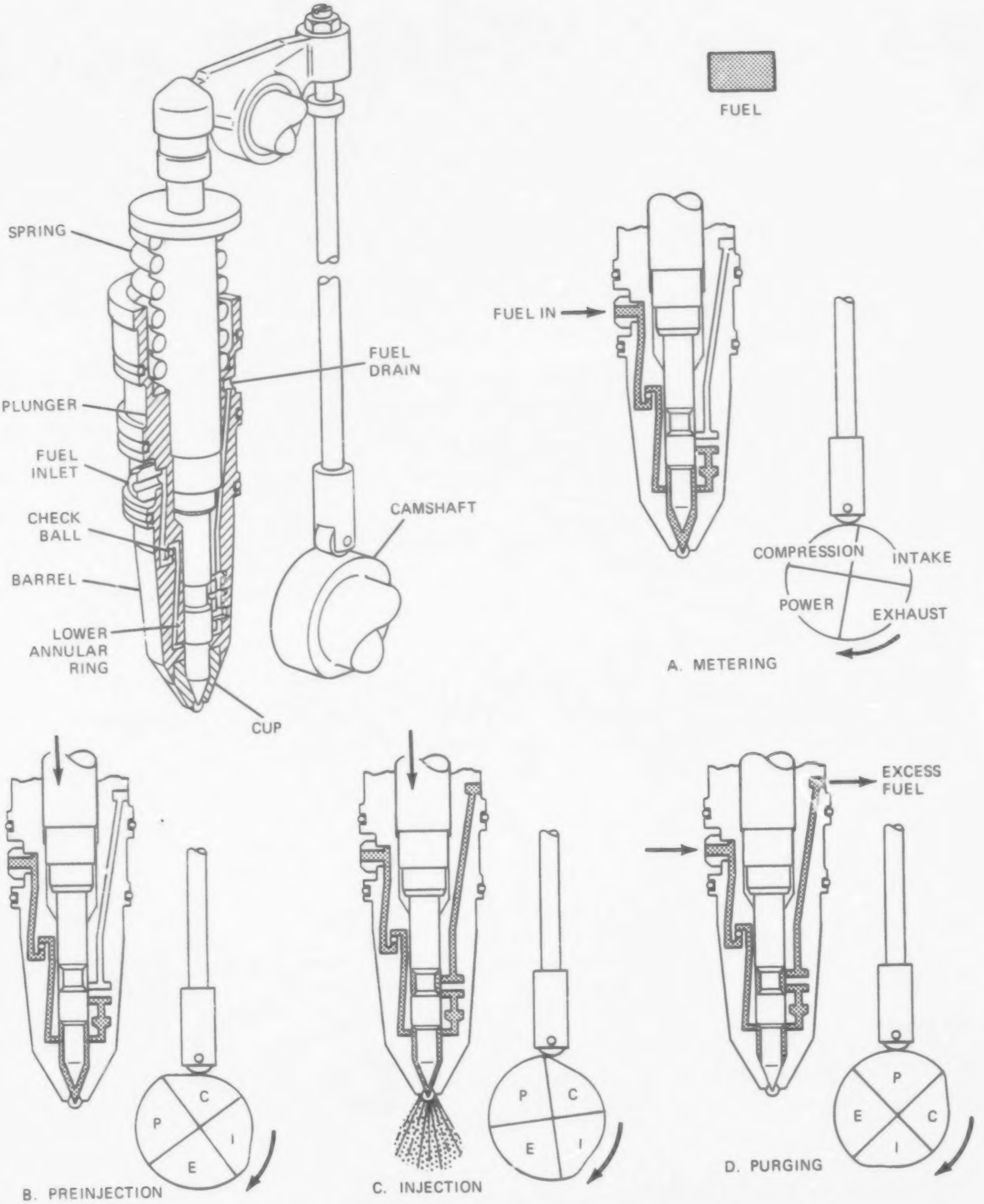

FUEL
SPRING
FUEL DRAIN
PLUNGER
FUEL INLET
CHECK BALL
CAMSHAFT
BARREL
LOWER ANNULAR RING
CUP
FUEL IN
COMPRESSION
INTAKE
POWER
EXHAUST
A. METERING
EXCESS FUEL
C
P
I
E
B. PREINJECTION
P
C
E
I
C. INJECTION
P
E
C
I
D. PURGING

Figure 5-18. Pressure-Timed Delivery Injector Operation.

TA233454

almost at the end of the compression stroke, and the fuel is being pressurized by the plunger.

(3) *Injection (C, Fig. 5-18).* The plunger is almost all the way down, the fuel is injected out the eight orifices, and the engine is on the very end of the compression stroke.

(4) *Purging (D, Fig. 5-18).* The plunger is all the way down, injection is finished, and the fuel is flowing into the injector, around the lower annular groove, up a drilled passageway in the barrel, around the upper annular groove, and out through the fuel drain. The cylinder is on the power stroke. During the exhaust stroke, the plunger moves up and waits to begin the cycle all over again.

5-19. PSB Distributor Injection System.

a. Overall System Operation (Fig. 5-19). The PSB distributor system, like the distributor system described in paragraph 5-16, uses a pump that sends measured charges of fuel to each injector at a properly timed interval. The difference in the PSB system is that the charges of fuel are sent directly from the pump at the high pressure that is necessary for injection. This eliminates the need for unit-type injectors and the associated linkage and camshafts, making the system less cumbersome. The injectors are of the same basic design as the ones used in the multiple unit injection system (para 5-14). The nozzles usually are of the hole type (para 5-14).

b. The PSB Injector Pump. The PSB injection pump (Fig. 5-20) is compact and self-contained, housing all components of the injectors. Operation is shown in figure 5-21.

(1) The PSB pump contains a plunger-type pump that creates the high-pressure fuel charges for the injectors. The pump is driven by a camshaft

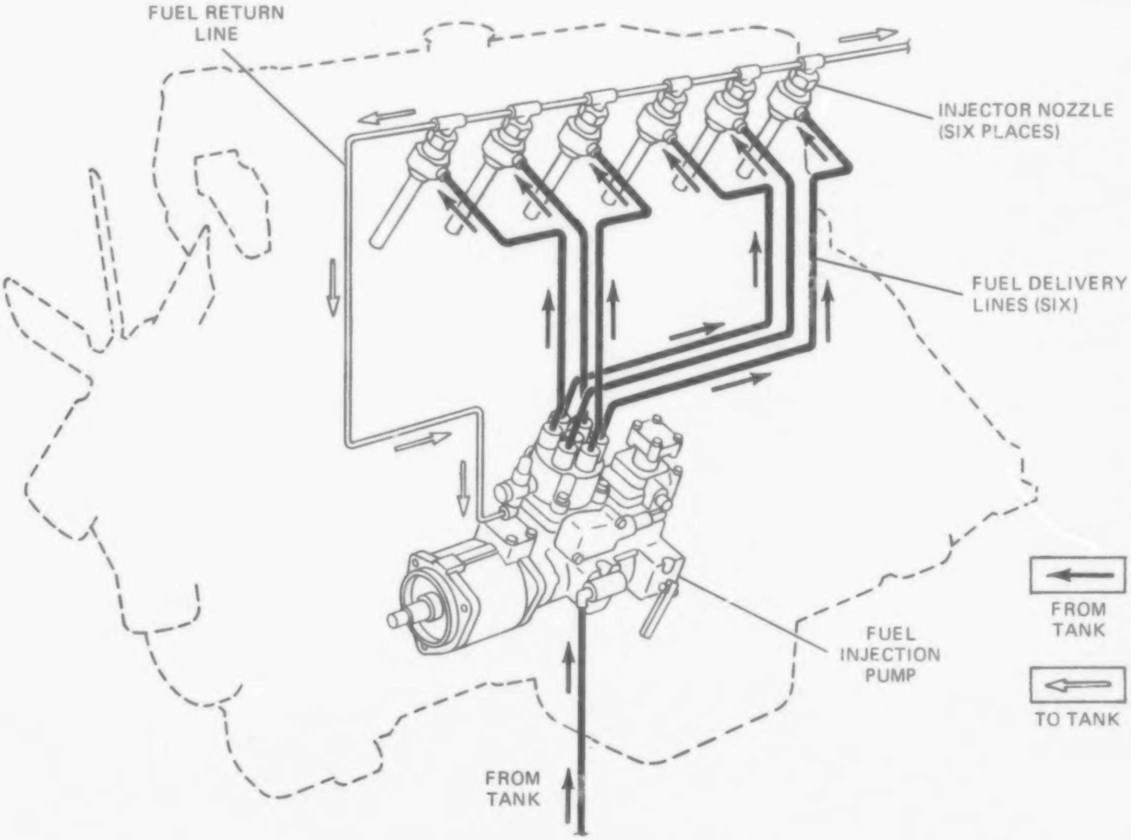
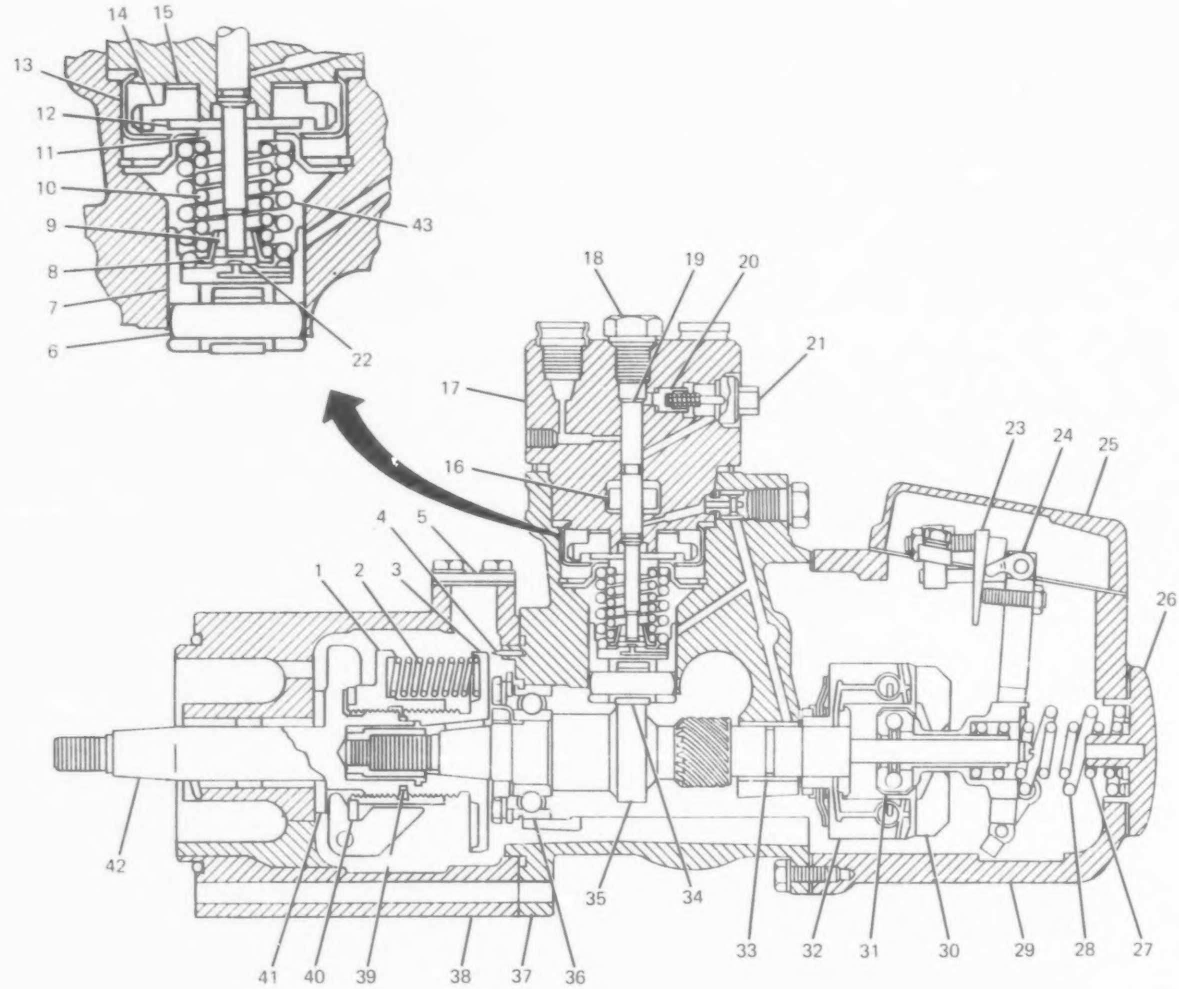


Figure 5-19. PSB Distributor Injection System.

TA233455

159

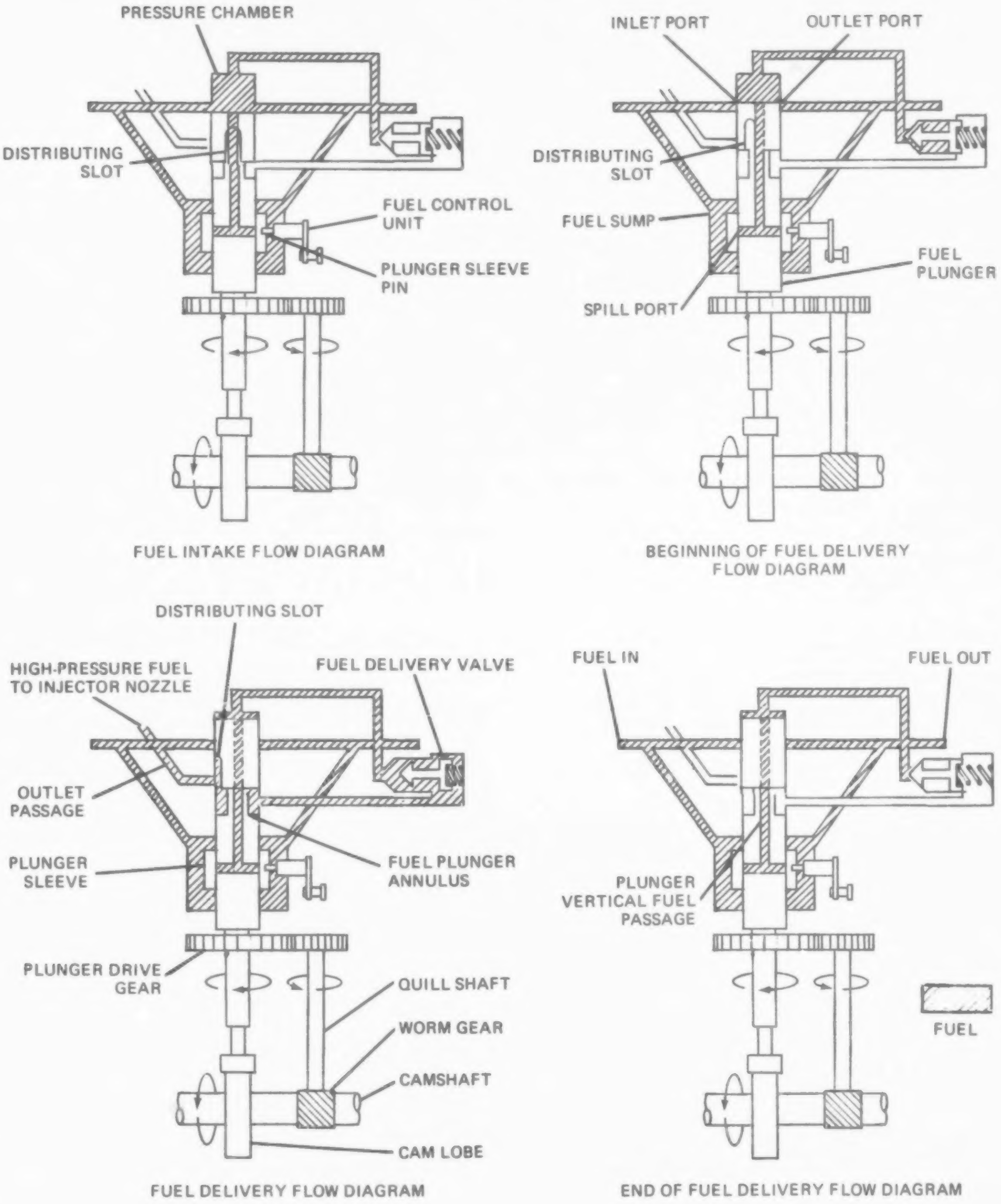


1. SLIDING GEAR
2. TIMING DEVICE SPRING
3. TIMING DEVICE HUB
4. TIMING POINTER
5. TIMING COVER
6. TAPPET ROLLER PIN
7. TAPPET GUIDE
8. SPRING LOWER SEAT
9. PLUNGER LOCK
10. PLUNGER INNER SPRING
11. SPRING UPPER SEAT
12. PLUNGER GUIDE
13. DRIVE GEAR RETAINER
14. PLUNGER DRIVE GEAR
15. GEAR THRUST WASHER
16. PLUNGER SLEEVE
17. HYDRAULIC HEAD
18. PLUNGER BORE SCREW
19. FUEL PLUNGER
20. FUEL DELIVERY VALVE
21. DELIVERY VALVE SCREW
22. PLUNGER BUTTON
23. STOP PLATE
24. SMOKE LIMIT CAM
25. GOVERNOR COVER
26. GOVERNOR END CAP
27. GOVERNOR INNER SPRING
28. GOVERNOR OUTER SPRING
29. GOVERNOR HOUSING
30. GOVERNOR WEIGHT
31. SLIDING SLEEVE
32. FRICTION DRIVE SPIDER
33. CAMSHAFT BUSHING-TYPE BEARING
34. TAPPET ROLLER
35. CAMSHAFT
36. CAMSHAFT BALL BEARING
37. INJECTION PUMP HOUSING
38. TIMING DEVICE HOUSING
39. END PLAY SPACER
40. SLIDING GEAR SPACER
41. SPIDER THRUST PLATE
42. WEIGHT AND SPIDER ASSEMBLY
43. OUTER PLUNGER SPRING

Figure 5-20. PSB Injection Pump.

TA233456

160


PRESSURE CHAMBER
DISTRIBUTING SLOT
FUEL CONTROL UNIT
PLUNGER SLEEVE PIN
INLET PORT
OUTLET PORT
DISTRIBUTING SLOT
FUEL SUMP
FUEL PLUNGER
SPILL PORT
DISTRIBUTING SLOT
HIGH-PRESSURE FUEL TO INJECTOR NOZZLE
FUEL DELIVERY VALVE
OUTLET PASSAGE
PLUNGER SLEEVE
FUEL PLUNGER ANNULUS
PLUNGER DRIVE GEAR
QUILL SHAFT
WORM GEAR
CAMSHAFT
CAM LOBE
FUEL IN
FUEL OUT
PLUNGER VERTICAL FUEL PASSAGE
FUEL

FUEL INTAKE FLOW DIAGRAM

BEGINNING OF FUEL DELIVERY FLOW DIAGRAM

FUEL DELIVERY FLOW DIAGRAM

END OF FUEL DELIVERY FLOW DIAGRAM

Figure 5-21. PSB Injection Pump Operation.

TA233457

that is contained within the PSB unit. Fuel is delivered to the PSB pump from the fuel tank by the fuel delivery pump at a regulated pressure of approximately 20 psi (137.9 kPa). The low-pressure fuel supply enters the pump chamber through the inlet port when the plunger is retracted fully. As the plunger begins its delivery stroke, the fuel inlet passage is blocked, trapping fuel in the pump chamber. The delivery stroke of the plunger then pushes the charge of fuel out of the chamber through the delivery passage. The high-pressure fuel charge then unseats the delivery valve, allowing it to flow into the distribution chamber.

(2) The pump plunger has a spoollike recess in its diameter about halfway down its sides that, in conjunction with the pump cylinder, forms the distribution chamber. A slot is cut into the plunger at the top of the distribution chamber. As it reciprocates, the plunger also is rotated through a quill gear. As it rotates, the slot lines up with equally spaced passages around the inside of the plunger bore. Each passage is connected to a fuel injector. The reciprocating and rotating motion are timed so that the plunger will go through a delivery stroke as the slot lines up with each injector passage. This enables the PSB injector pump to deliver a fuel charge to each consecutive injector every time the plunger makes one complete revolution.

(3) The PSB pump is geared to the engine so that the camshaft rotates at crankshaft speed. The cam contains half as many lobes as the engine has cylinders (there would be three cam lobes if the engine had six cylinders). The pump plunger is geared to rotate at one-half of camshaft speed. This arrangement allows the PSB pump to deliver a charge of fuel to each injector for every two crankshaft revolutions corresponding to the requirements of a four-stroke cycle diesel.

(4) A hole called a spill port is drilled through the lower portion of the pump plunger. The spill port is connected to the pump chamber by another drilled passage. The spill port is covered by a plunger sleeve whose position is adjusted by the control lever through an eccentrically mounted pin.

(5) The movement of the control lever controls the up and down position of the plunger sleeve. The position of the control lever is determined by the governor (para 5-25). When the sleeve is in its extreme downward position, the spill port is immediately uncovered as the plunger begins its delivery stroke. This causes all of the pressure from the pump chamber to bleed off to the pump return. In this position, there will be no fuel delivery to the injectors.

(6) When the plunger sleeve is in the extreme upward position, the spill port is covered until the plunger almost reaches the end of the delivery stroke. This position will deliver maximum fuel to the injectors. As the plunger moves upward, the pressure developed in the pump chamber unseats the delivery valve. Fuel flows into the distribution chamber and is sent to whatever injector is scheduled to receive it by the slot in the plunger.

(7) The amount of fuel delivered by each injection charge will increase proportionately as the plunger sleeve is moved from its extreme downward to its extreme upward position. The higher the plunger sleeve, the longer the effective pump stroke (plunger movement before the spill port is uncovered).

Section IV. FUEL SUPPLY PUMPS

5-20. General. Fuel injection pumps must be supplied with fuel under pressure for the following reasons:

a. The injection pumps lack the suction ability to draw fuel from the tank by themselves.

b. It is important to supply fuel to the injection pump in excess so that fuel may be used to cool and lubricate the system before bypassing it back to the tank.

c. Without a supply pump, the system would lose its prime whenever the pump is in the no-delivery mode.

The supply pumps in use generally are of the positive displacement type with a performance that is independent of any reasonable variations in viscosity, pressure, or temperature of the fuel. In a majority of the equipment, the fuel supply pump is built into the injection pump unit. This cuts down on fuel tubing and the complexity of the equipment, and allows the supply pump to share the same engine power takeoff as the injection pump.

5-21. Vane-Type Supply Pump. The basic overall operation of the vane-type supply pump is the same as the vane-type oil pump (para 20-6).

5-22. Plunger-Type Supply Pump (Fig. 5-22).

a. This type of pump always is mounted on the injection pump, where it is driven by the injection pump camshaft. It is a variable-stroke, self-regulating pump that will build pressure only up to a predetermined point.

b. Operation.

(1) The plunger follows the camshaft by the force of its plunger spring. As the follower comes off the high point of the cam lobe, the plunger moves toward the retracted position. This plunger movement creates a suction in the pump chamber, causing fuel to enter through the inlet valve.

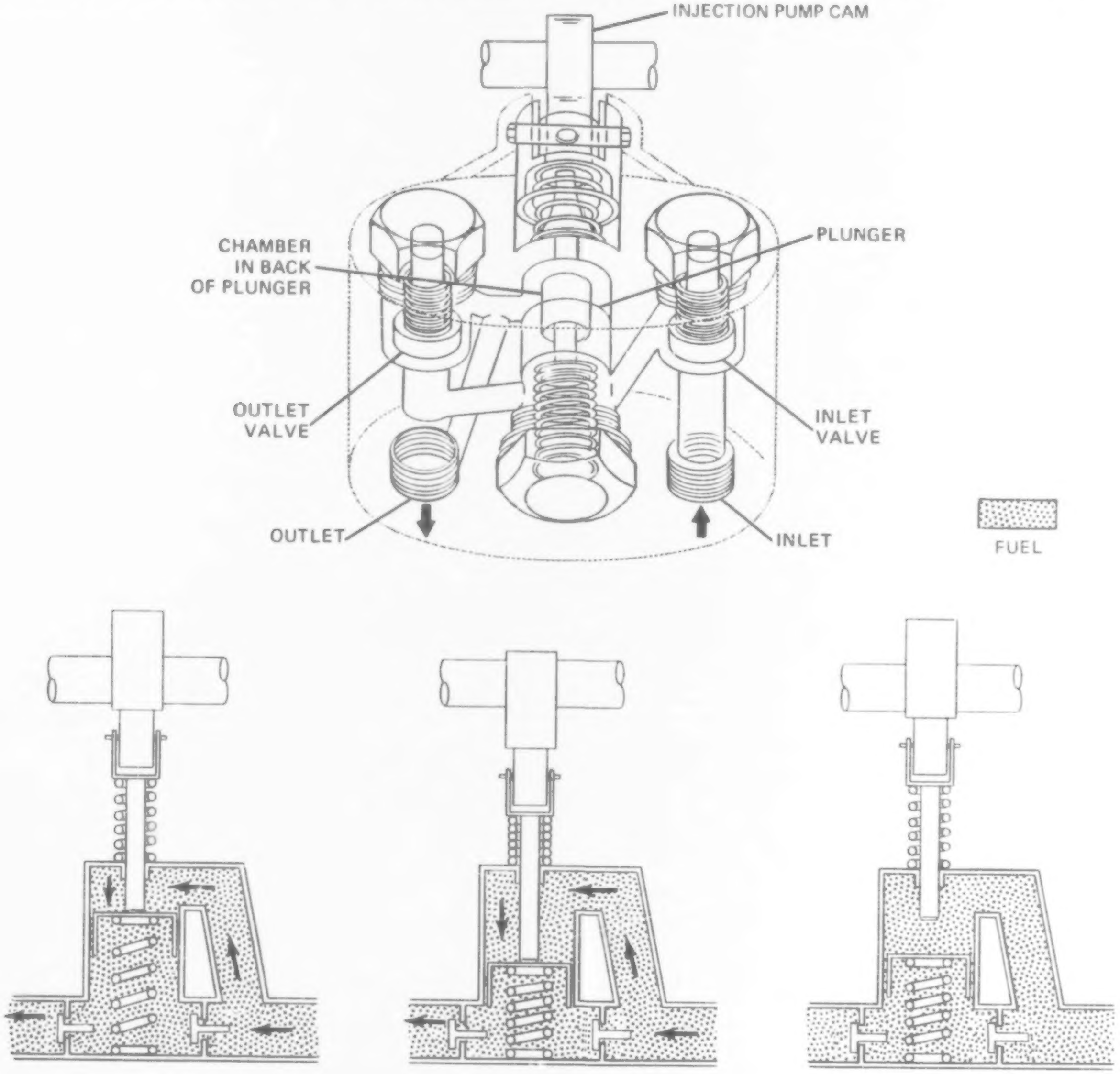

INJECTION PUMP CAM
CHAMBER IN BACK OF PLUNGER
PLUNGER
OUTLET VALVE
INLET VALVE
OUTLET
INLET
FUEL

Figure 5-22. Plunger-Type Supply Pump.

TA233458

(2) As the cam lobe comes around again, it forces the plunger upward. This forces the fuel out of the chamber through the outlet valve and to the injection pump.

(3) The cam follower drives the plunger through a spring. The spring is calibrated so that it will flex rather than drive the plunger when the pressure in the pump chamber reaches the desired maximum. This effectively regulates pump pressure.

5-23. Gear-Type Supply Pump. The basic overall operation of the gear-type supply pump is the same as the gear-type oil pump (para 20-4).

Section V. GOVERNORS

5-24. General. All diesel engines require governors to prevent overspeeding of the engines under light loads. Automotive diesel engines also demand control of idling speed. Any of the governors provide a variable-speed control that, in addition to controlling minimum and maximum speeds, will maintain any intermediate speed desired by the operator. Engine speed in a diesel is controlled by the amount of fuel injected. The injection, therefore, is designed to supply the maximum amount of fuel that will enable it to operate at full load while reaching a predetermined maximum speed (rpm). If, however, the maximum fuel charge were supplied to the cylinders while the engine was operating under a partial or unloaded condition, the result would be overspeeding and certain failure. Thus, it can be seen that the governor must control the amount of fuel injected in order to control the engine speed.

5-25. Actuation. Governors may be actuated through the movement of centrifugal flyweights or by the air-pressure differential produced by a governor valve and venturi assembly.

The centrifugal flyweight type may incorporate a mechanical linkage system to control the injection pump, or it may include a hydraulic system to transmit the action of the weights to the pump. On engines where the rate of acceleration must be high, the governor-controlling weights must be small to obtain the required rapid response from the governor. The problem is that the smaller flyweights will not exert enough force to control the injection pump properly. When this is the case, the flyweights will be used to control a hydraulic relay valve, which, in turn, will control the injection pump through a servo piston.

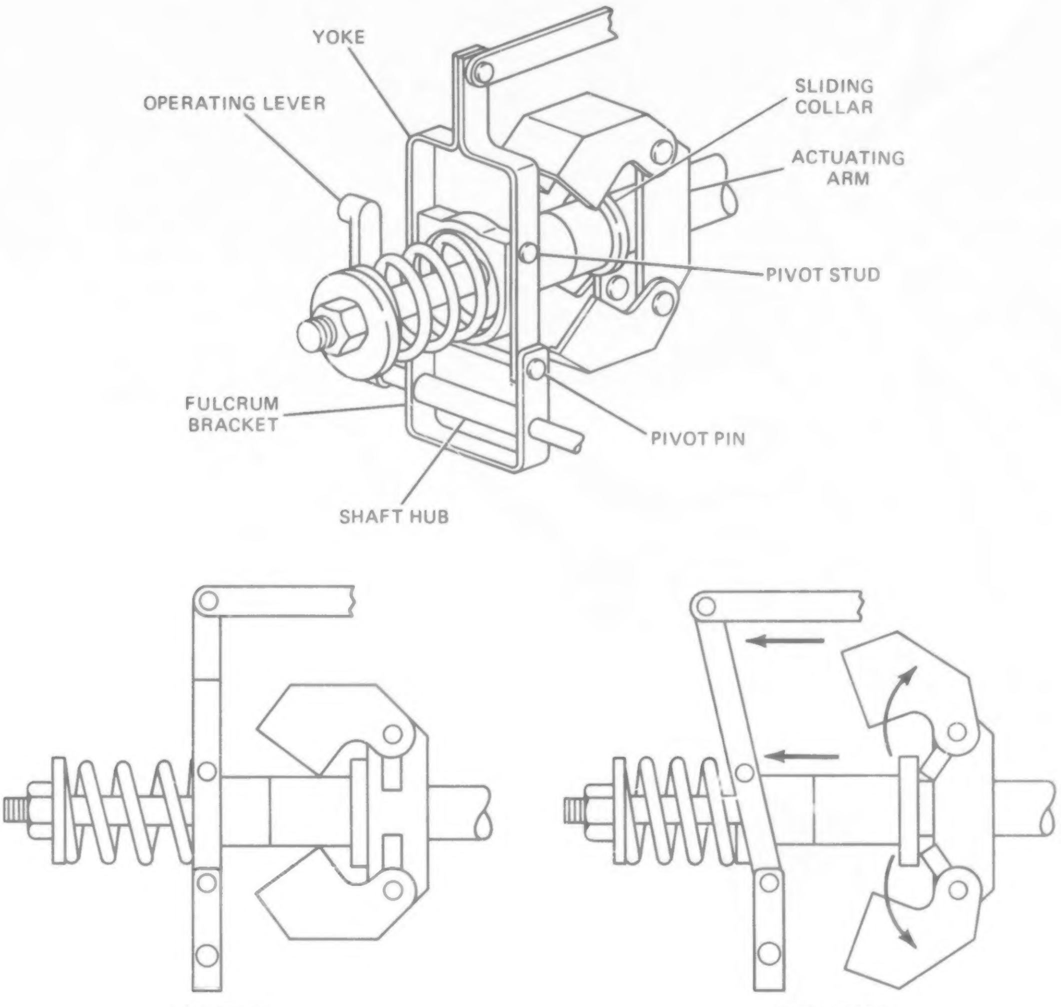
5-26. Mechanical (Centrifugal) Governors (Fig. 5-23).

a. The operation of the mechanical governor is based on the centrifugal force of rotating weights counterbalanced by springs. When the speed of the engine increases, the weights fly outward, pulling with them suitable linkage to change the setting of the pump control rod. The governor linkage is connected to the injection pump in such a manner that the spring moves the control mechanism toward the full-fuel position. The outward movement of the governor flyweights, through the sliding governor sleeve, will move the pump control rod toward the no-fuel position against the force of the governor spring.

b. With this type of governor, the operator controls the tension of the governor spring to control the quantity of fuel rather than operating the fuel control rod directly. The fuel delivery control system of the injection pump is connected to the governor yoke in such a manner that any movement of the yoke will affect directly the quantity of the fuel injected. The spring tension is controlled by the operating lever, the movement of which is determined by the position of the foot throttle. The travel of the operating lever is limited by the idle and maximum-speed screws. When the weights are fully collapsed (engine stopped), the spring moves the sliding sleeve and yoke so that the fuel injection pump is in the full-fuel position. When the weights are fully extended, the sliding sleeve and the yoke move to the rear and decrease the amount of fuel delivered.

c. If the load on the engine is decreased, the engine tends to accelerate. However, when the engine does accelerate, the increased centrifugal force causes the governor flyweights to move outward, resulting in the movement of the fuel control rod through the governor sleeve toward the no-fuel position. This will cause an equilibrium to develop between the flyweights and the governor spring. The movement of the operating lever varies the spring tension. This will cause a change in the point of equilibrium between the

164



LOW SPEED

HIGH SPEED

Figure 5-23. Mechanical (Centrifugal) Governor.

spring and the flyweights, effectively changing the engine speed for any given load.

d. To accelerate the vehicle with a given load, the foot throttle is depressed, which in turn increases the governor spring tension. The increase in tension causes the governor sleeve to move the control rod through the yoke toward the full-fuel position. As engine speed increases, the flyweights will move outward until they reach the point of equilibrium with the governor spring. At this point, engine speed will stabilize.

5-27. Vacuum Governors (Fig. 5-24).

a. The vacuum governor operates by utilizing the pressure drop created by the velocity of the air passing through a venturi located in the air-intake manifold. The governor consists essentially of an atmospheric suspended diaphragm connected by linkage to the control rod of the injection pump. The chamber on one side of the diaphragm is open to atmosphere, and on the other side it is sealed and connected to the venturi in the manifold. In addition, there is a spring acting on the sealed side of the chamber, which moves the diaphragm and the control rod to the full-fuel position normally.

b. When the engine is running, the pressure in the sealed chamber is reduced below the atmospheric pressure existing in the other chamber.

TA233459

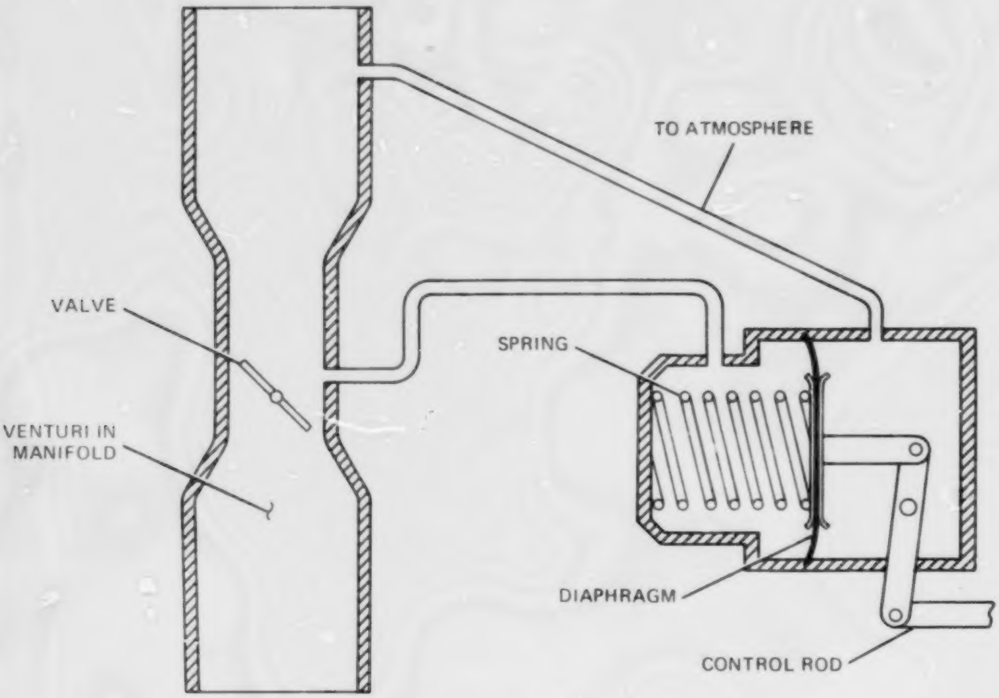


Figure 5-24. Vacuum-Operated Governor.

The amount of pressure reduction depends on the position of the governor valve and speed of the engine. It is this pressure differential that positions the diaphragm and, consequently, the control rod of the injection pump. The governor valve is controlled by a lever that is connected by suitable linkage to the foot throttle. There is no mechanical connection between the foot throttle and the control rod of the injection pump.

c. If the engine is operating under load and the speed (rpm) is below governed speed, the velocity of air passing through the venturi is comparatively low and only a slight pressure differential is present. This will cause the spring to move the diaphragm and the injector pump control rack toward the full-fuel position. As the engine speed picks up, the pressure differential on both sides of the diaphragm and the spring will achieve equilibrium and the position of the control rod will stabilize. The same operating principles will apply in reverse to prevent engine overspeed. As the engine speed increases, the velocity of air through the venturi increases, causing a corresponding increase in the pressure differential on both sides of the diaphragm. The increase in pressure differential causes the diaphragm and the control rod to move against the pressure of the spring toward the no-fuel position. The control rod's position will stabilize when equilibrium is achieved in the diaphragm unit. When the engine is operating at wide-open throttle, the pressure differential will be almost zero and spring force will position the control rack in the full-fuel position.

d. For any position of the governor valve between idling and full load of the engine, the diaphragm finds its relative position. Because any movement of the diaphragm also is transmitted to the control rod, the amount of fuel delivery definitely is controlled at all speeds. The diaphragm is moved in the direction of less fuel delivery as the pressure drop between the chambers is increased. The spring will move the control rod in the direction of greater fuel delivery as the pressure drop is decreased.

TA233460

Section VI. TIMING DEVICE

5-28. General. A large percentage of fuel injection pumps have timing devices incorporated in them. Varying the time when fuel injection begins will improve diesel engine performance and fuel economy for the same reasons that varying spark timing will improve the performance of a gasoline engine (para 2-25).

5-29. Description (Fig. 5-25).

a. The timing device usually consists of an aluminum casting with mounting flanges at both ends. A bore in the housing guides and supports the spider assembly. A timing opening with cover is located in the top of the housing and is used to observe the position of the timing pointer in relation to the timing mark on the timing device hub during injection pump timing procedures.

b. The timing device hub, with external left-hand helical splines for engaging the internal helical splines of the sliding gear, has a tapered

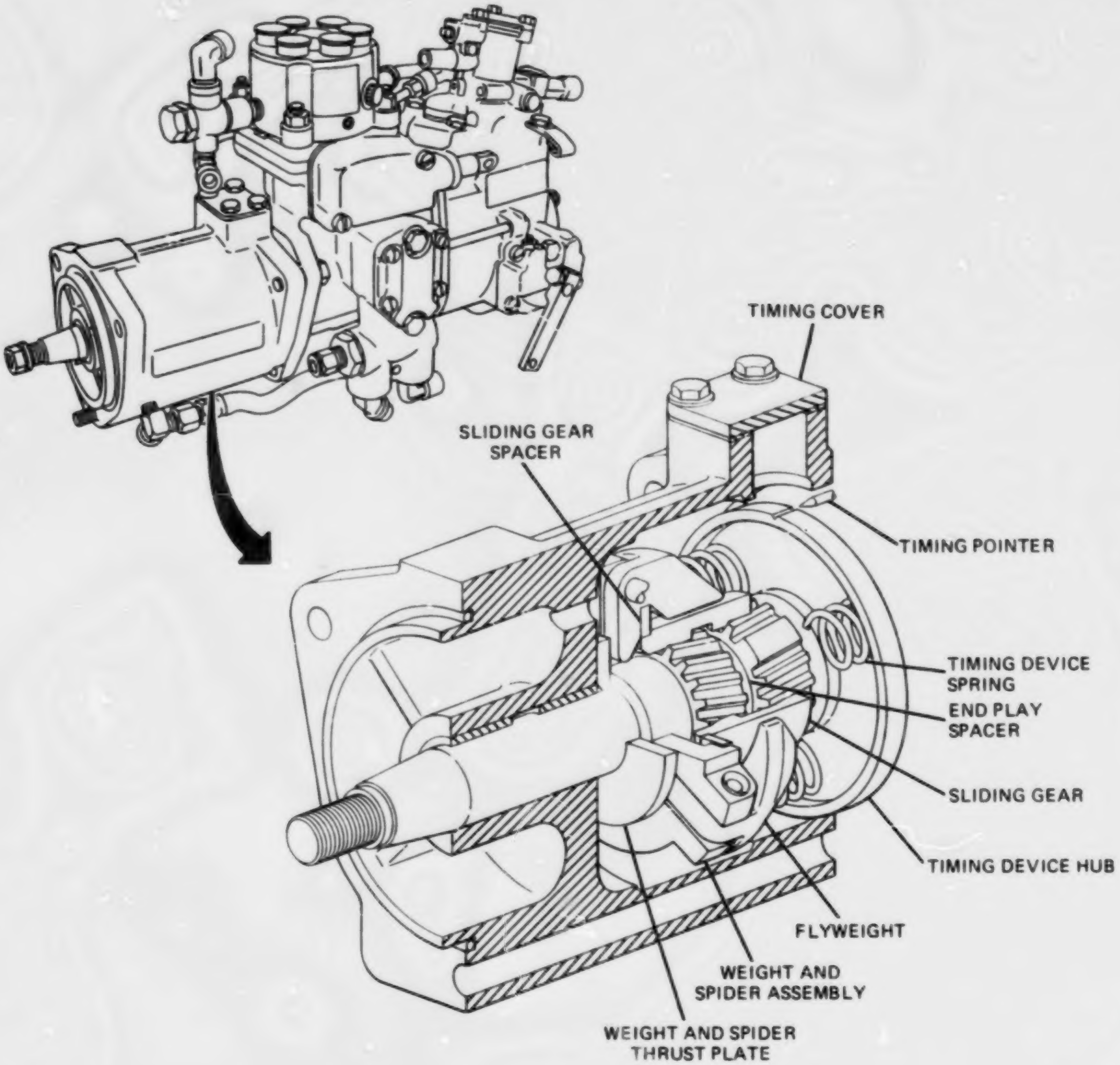

TIMING COVER
SLIDING GEAR SPACER
TIMING POINTER
TIMING DEVICE SPRING
END PLAY SPACER
SLIDING GEAR
TIMING DEVICE HUB
FLYWEIGHT
WEIGHT AND SPIDER ASSEMBLY
WEIGHT AND SPIDER THRUST PLATE

Figure 5-25. Timing Device.

TA233461

bore and keyway. The hub is secured to the camshaft extension by a woodruff key, nut, and setscrew. The hub usually is counterbored to receive the timing device springs. The springs oppose the flyweight forces of the weight and spider assembly.

c. The weight and spider assembly has external right-hand helical splines to mesh with the internal helical splines of the sliding gear. The splined end is machined to receive the end play spacer. Three flyweights are pinned to a flange adjacent to the splines. The weight and spider thrust plate located between the flange and the timing device housing carries the back thrust of the flyweights and prevents housing wear.

d. The sliding gear has internal left-hand helical splines at one end and internal right-hand helical splines at the other end and meshes with the external splines of both the weight and spider assembly and the timing device hub. Correct assembly of the spline train is ensured by a wide land on both the hub and weight and the spider assembly. The sliding gear has a missing tooth on each set of internal splines to receive the wide lands. Three arms extend from the outer surface of the sliding gear to provide seats for the three timing device springs. The force on these springs is controlled by a sliding gear spacer.

5-30. Operation (Fig. 5-26).

a. As the engine rotates the weight and spider assembly, centrifugal force opens the flyweights from their collapsed position against the force of the three timing device springs.

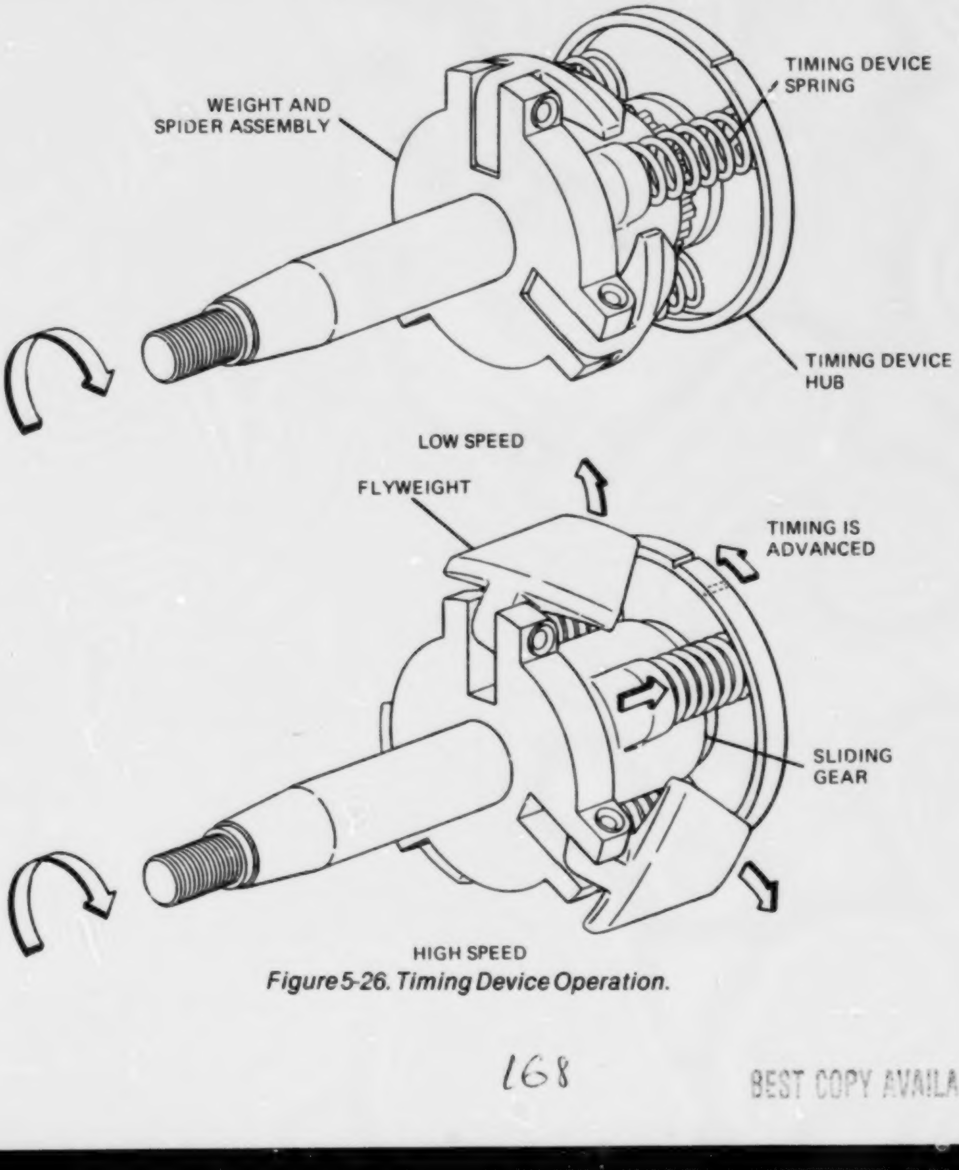


Figure 5-26. Timing Device Operation.

TA233462

168

b. As the flyweights swing out, the sliding gear is forced toward the timing device hub.

c. The longitudinal movement of the sliding gear on its helical spline causes a slight change in the rotational relationship in the injection pump to the engine, causing injection to begin slightly earlier in the power stroke.

Section VII. COLD WEATHER STARTING AIDS

5-31. Purpose. Diesel engines are very difficult to start in cold weather. This is due mainly to the low volatility of the fuel. The two most popular methods of assisting a diesel engine in starting are:

a. Preheating the induction air in the intake manifold so that adequate vaporization will take place for combustion.

b. Injecting a fuel into the engine that remains volatile enough in cold weather to initiate combustion.

5-32. Intake Manifold Flame Heater System (Fig. 5-27).

a. General. Engines are equipped with a flame-type manifold heater for heating the induction air during cold weather starting and warmup operations.

b. Operation. The flame heater assembly is composed of a housing, spark plug, flow control nozzle, and two solenoid control valves.

The spark plug is energized by the flame heater ignition unit. The nozzle sprays fuel under pressure into the intake manifold elbow assembly. The fuel vapor is ignited by the spark plug and burns in the intake manifold, heating the air before it enters the combustion chambers.

(1) Because this system uses fuel from the fuel tank of the vehicle, its components must be compatible with all approved fuels when the system is used with a multifuel engine.

(2) The flame fuel pump assembly is a rotary type, driven by an enclosed electric motor. The fuel pump receives fuel from the vehicle fuel tank through the vehicle's supply pump and delivers it to the spray nozzle. The pump is energized by an ON-OFF switch located on the instrument panel.

(3) The intake manifold flame heater system has a filter to remove impurities from the fuel before it reaches the nozzle.

(4) Two fuel solenoid valves are used in the flame heater system. The valves are energized (open) whenever the flame heater system is activated. The valves ensure that fuel is delivered only when the system is operating. They stop fuel flow the instant that the engine, or heater system, is shut down.

5-33. Ether Injection System (Fig. 5-28).

a. General. The ether injection system assists in the cold weather starting of a diesel engine by injecting ether into the intake manifold. Ether, which is very volatile, will vaporize readily in cold weather, initiating combustion.

b. Operation. A pressurized canister containing ether is fitted to the engine. The flow of ether from the canister to the spray nozzle is controlled by a solenoid valve that closes when it is deenergized. This solenoid is controlled by a pushbutton switch on the instrument panel.

(1) When the switch is pushed, the solenoid is energized. This opens the ether canister. Pressure from the canister pushes ether through a connecting tube to the nozzle, where it discharges into the intake.

(2) The system contains a coolant temperature sensor that will keep the system from functioning when coolant temperature is above 50°F (10°C).

169

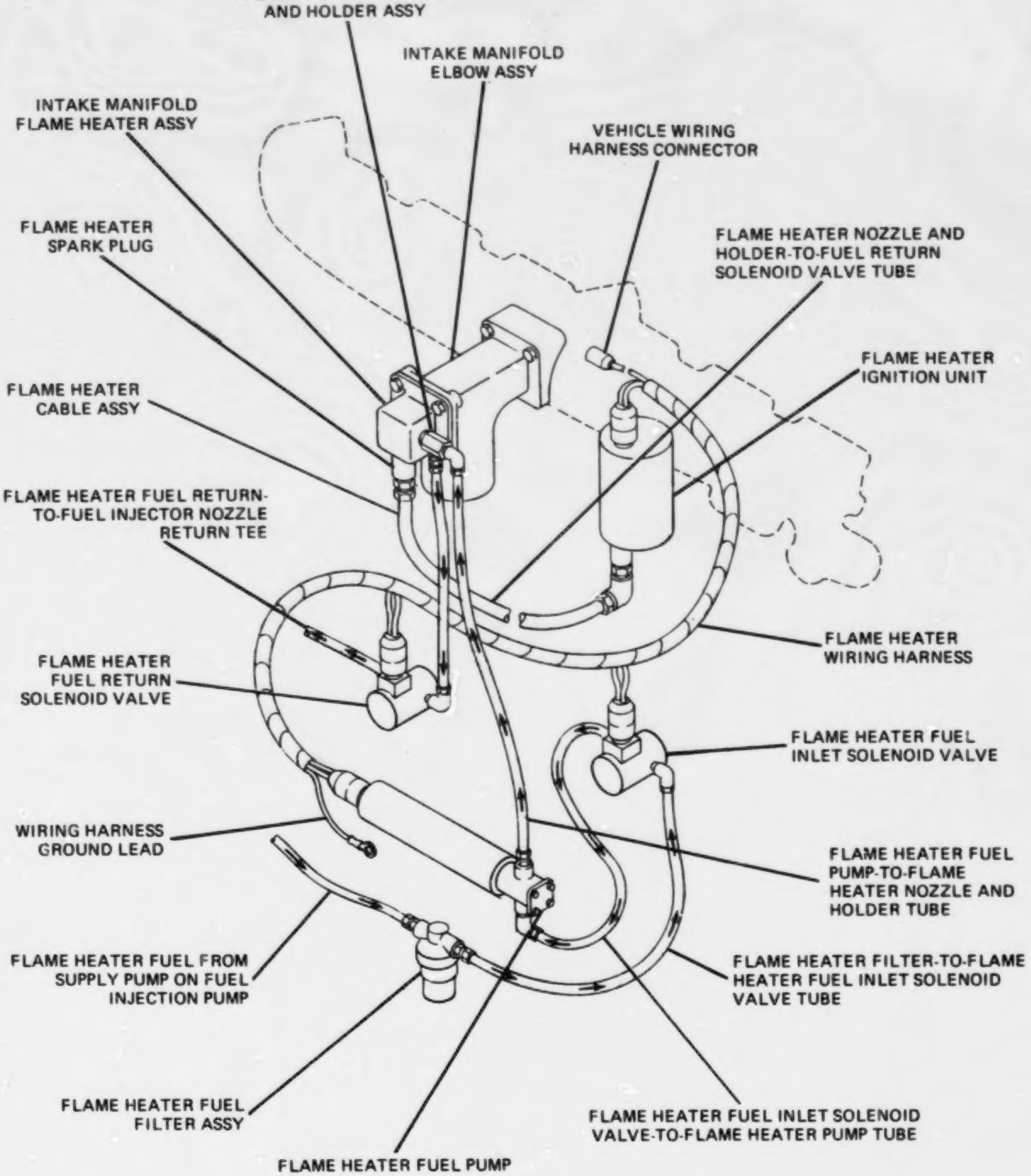

FLAME HEATER NOZZLE AND HOLDER ASSY
INTAKE MANIFOLD ELBOW ASSY
INTAKE MANIFOLD FLAME HEATER ASSY
VEHICLE WIRING HARNESS CONNECTOR
FLAME HEATER SPARK PLUG
FLAME HEATER NOZZLE AND HOLDER-TO-FUEL RETURN SOLENOID VALVE TUBE
FLAME HEATER IGNITION UNIT
FLAME HEATER CABLE ASSY
FLAME HEATER FUEL RETURN-TO-FUEL INJECTOR NOZZLE RETURN TEE
FLAME HEATER WIRING HARNESS
FLAME HEATER FUEL RETURN SOLENOID VALVE
FLAME HEATER FUEL INLET SOLENOID VALVE
WIRING HARNESS GROUND LEAD
FLAME HEATER FUEL PUMP-TO-FLAME HEATER NOZZLE AND HOLDER TUBE
FLAME HEATER FUEL FROM SUPPLY PUMP ON FUEL INJECTION PUMP
FLAME HEATER FILTER-TO-FLAME HEATER FUEL INLET SOLENOID VALVE TUBE
FLAME HEATER FUEL FILTER ASSY
FLAME HEATER FUEL INLET SOLENOID VALVE-TO-FLAME HEATER PUMP TUBE
FLAME HEATER FUEL PUMP

Figure 5-27. Manifold Flame Heater System.

TA233463

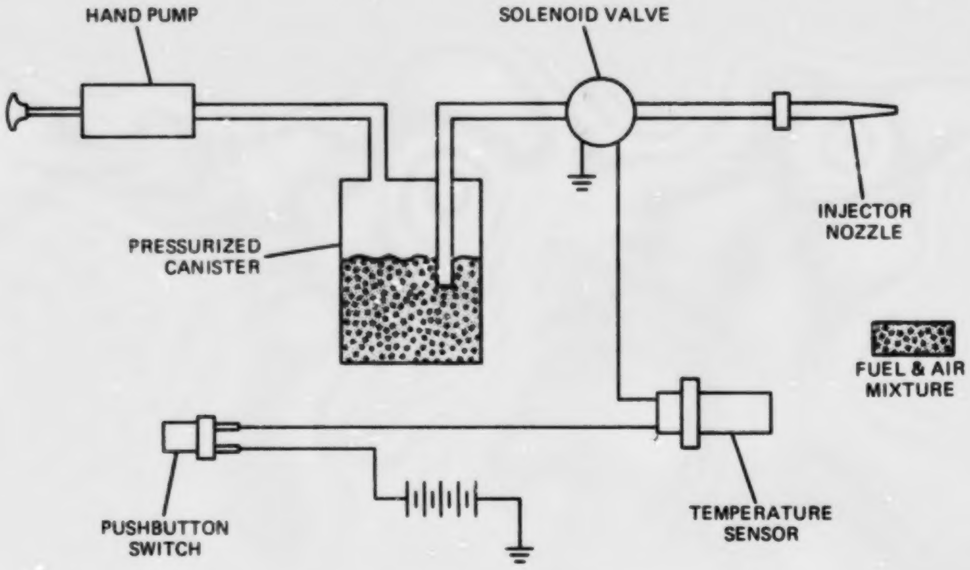


Figure 5-28. Ether Injection System.

Section VIII. FUEL FILTERS

5-34. General. Thorough and careful filtration is necessary especially to keep diesel engines efficient. Diesel fuels are more viscous than gasoline and contain more gums and abrasive particles that may cause premature wear of injection equipment. The abrasives may consist of material that is difficult to eliminate during refining, or they even may enter the tank during careless refueling. Whatever the source, it is imperative that means be provided to protect the system from abrasives.

5-35. Configuration. Most diesel engine designs include at least two filters in the fuel supply systems to protect the closely fitted parts in the pumps and nozzles. The primary filter usually is located between the fuel tank and the fuel supply pump. The primary filter contains a coarse filter medium that removes the larger foreign matter. The secondary filter usually is located between the fuel supply pump and the fuel injection pump. The secondary filter contains a fine filter medium that removes even the most minute traces of foreign matter from the fuel. Additional filtering elements frequently are installed between the injection pump and the nozzle.

5-36. Types. Diesel fuel oil filters are referred to as full-flow filters, because all the fuel must pass through them before reaching the injection pumps. A diesel fuel filter usually incorporates an air valve to release any air that might accumulate in the filter during operation.

a. Primary Filters (Fig. 5-29). Metal filters are used as primary filters because the fine particles that will pass through them are not injurious to the supply pump. The filter element is usually of the metal disk type, as described in paragraph 4-2. Solids larger than 0.005 in. (0.127 mm) remain outside the metal disks, while the larger foreign matter and the majority of the water settles to the bottom of the bowl. From here, the foreign matter can be removed through a drainplug. A ball relief valve in the filter cover enables the oil to bypass the filter element if the disks become clogged.

b. Secondary Filters (Fig. 5-30). Fabric filters, because of their greater filtering qualities, are used principally as main filters for protecting the fuel injection pump. Many of the filters in use are similar to the lubricating oil filters described in paragraph 8-13. The bag-type filter also is used. The filtering medium is a large bag of close, evenly woven, lintless, acid-resisting textile material. Maximum benefit is derived from the bag's large area by keeping the sides of the

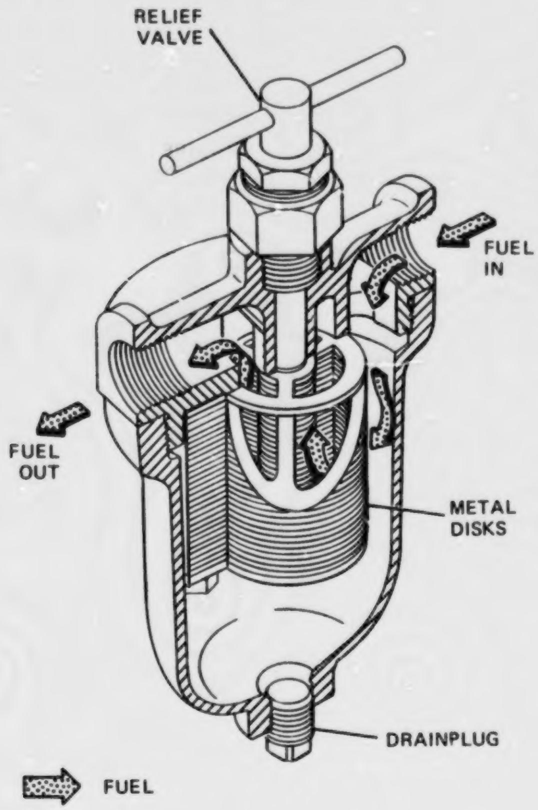


Figure 5-29. Primary Fuel Filter.

bag separated by a wire-screen mat. The screen is the same size as the bag, and the two are fastened detachably to a central feeding spool and wound around it. Layers of bag and screen thus are alternated through the winding, and the entire surface of the bag is available for filtering purposes. The fuel to be filtered flows from the filter inlet at the top, through the spool, and out of the ports to the inside of the bag. The dirt, solids, abrasives, and carbon are caught in the bag, and the clean fuel passes outward and to the filter outlet. The bag may be removed, cleaned, and reinstalled.

TA233465

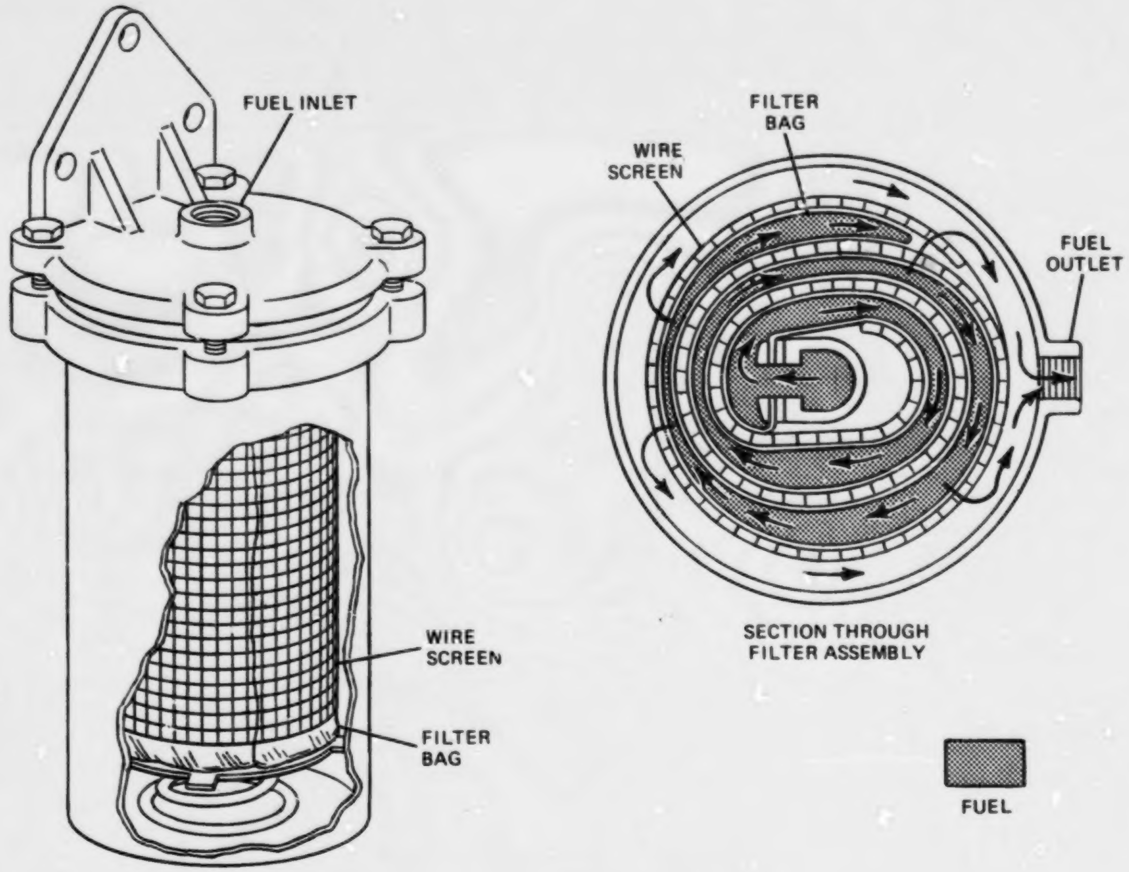


Figure 5-30. Secondary Fuel Filter.

Section IX. ENGINE RETARDER SYSTEM

5-37. Purpose. The engine retarder systems are used on many larger vehicles equipped with diesel engines. They are designed to provide additional stopping ability to a vehicle in motion. These systems also relieve the service brakes of excessive heat buildup and wear due to prolonged application. An auxiliary means of power absorption is used to accomplish the additional braking process. Basically, three different engine retarder systems currently are used; each is discussed below.

5-38. Compression Brake. The compression brake operates by restricting the exhaust gas flowing from the engine. The system basically consists of a butterfly valve fitted into the exhaust pipe between the exhaust manifold and muffler. The system is activated by a switch mounted in the cab. The valve is controlled by an air or vacuum switch mounted on the accelerator pedal. The system operates by restricting the exhaust gases, causing a pressure rise in the exhaust manifold. This pressure increase can vary from 30 to 40 psi (206.85 to 275.8 kPa). The compression brake causes a pressure buildup in the cylinder during the exhaust stroke. The engine then becomes a low-pressure pump driven by the wheels. This, in turn, slows down or retards the vehicle.

5-39. Hydraulic Retarder. The hydraulic retarder is a pedal-operated unit mounted in the transmission. This system assists the service brakes in controlling the vehicle's speed during long downhill braking or when slowing down in stop-and-go traffic. This system consists of a retarder cavity located between the converter and transmission

TA233466

housing. The cavity contains a rotor that is connected to the turbine output shaft. Stationary reaction vanes are mounted on both sides of the rotor. When the transmission fluid fills the cavity, it churns against the reaction vanes and slows down the rotor. The retarding efforts then are transmitted to the drive line to slow down the vehicle. The retarder will continue to operate as long as the retarder pedal is depressed. The rotational energy is transformed into heat energy and absorbed by the transmission fluid. If the retarder is operated continuously, the fluid temperature can rise faster than it can be cooled. Once this happens and the fluid temperature approaches a predetermined level, a warning light on the instrument panel indicates that the retarder operation should be discontinued until the fluid cools down and the warning light goes out. When the retarder pedal is released, the retarder valve closes and the fluid in the cavity automatically discharges and permits the rotor to turn without drag.

5-40. Jacobs Engine Brake. The Jacobs engine brake (Fig. 5-31) consists of a slave piston mounted over the exhaust valve. The system operates by opening the exhaust valve near the top of the compression stroke. This releases the compressed cylinder charge into the exhaust system. This blowdown of compressed air into the exhaust system prevents the return of energy from the piston on the expansion stroke. The result is an energy loss because the work done in compressing the charge is not returned to the usable energy. The system is operated by a three-position switch that allows the driver to select the degree of braking required. The three-position switch is set to allow braking on two, four, or all cylinders. This enables the driver to predetermine how much braking will be needed to properly slow down the vehicle.

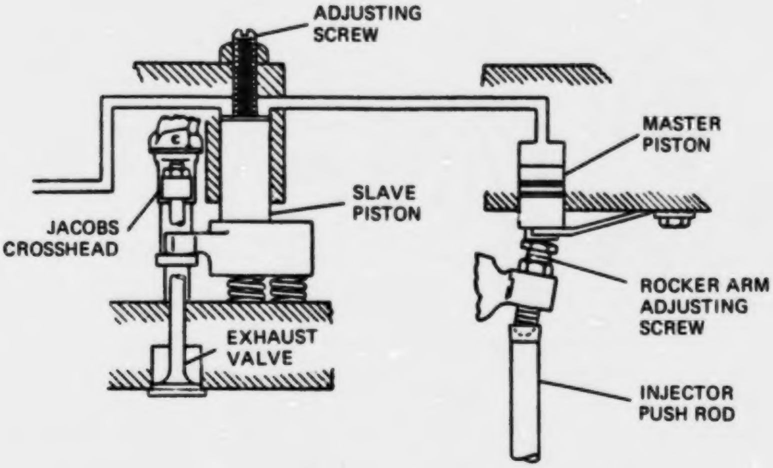


Figure 5-31. Jacobs Engine Brake.

TA233467

174

BEST COPY AVAILABLE

CHAPTER 6

PROPANE FUEL SYSTEMS

Section I. CHARACTERISTICS

6-1. Liquefied Petroleum Gas. Liquefied petroleum gas, or LPG, is used for fuel on some vehicles. This fuel remains a liquid under pressure and vaporizes when it comes in contact with the atmosphere. LPG fuel is stored in heavy steel tanks mounted on the vehicle. To keep the mixture liquefied, these tanks are pressurized between 20 and 175 psi (137.9 and 1206.6 kPa). The tanks also are filled between 80 and 90 percent of capacity to allow for thermal expansion. These pressurized fuel tanks eliminate the need for a fuel pump. LPG burns at a slower rate than gasoline, which results in smoother operation because of prolonged power impulses. Being a gas, LPG minimizes crankcase dilution and prolongs engine life.

Section II. BASIC SYSTEM

6-2. Operation. A typical LPG system is illustrated in figure 6-1. In this system, liquid fuel exits the storage tank by a tube mounted inside the supply tank. The tube is configured so that it is immersed in the liquid fuel at all times. The fuel then is routed to the first regulator. This regulator reduces pressure to 4 to 15 psi (27.58 to 103.42 kPa). The liquid fuel exits the regulator as half vapor and half liquid. The vapor and liquid combination then is heated, causing it to become all vapor. The second regulator reduces the pressure of the gas to atmospheric pressure. The gas then enters a carburetor or mixing valve and then enters the cylinders.

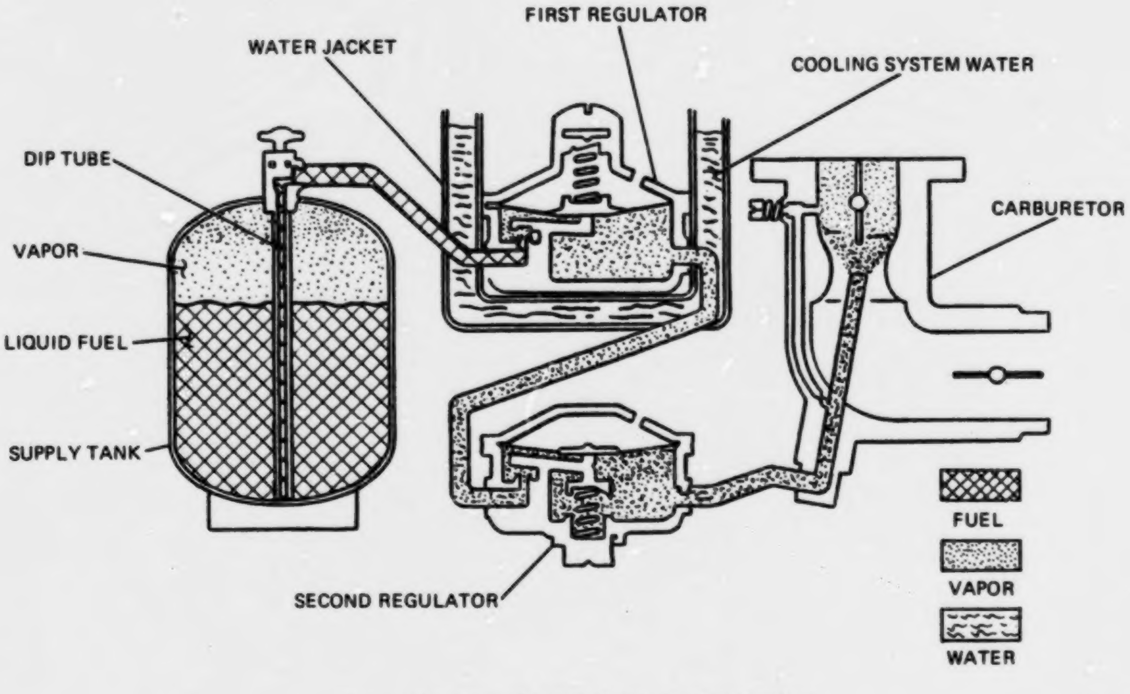


Figure 6-1. Liquefied Petroleum Gas System.

TA233468

CHAPTER 7

EXHAUST AND EMISSION CONTROL SYSTEMS

Section I. EXHAUST SYSTEM

7-1. Purpose (Fig. 7-1). The waste products of combustion are carried from the engine to the rear of the vehicle by the exhaust system, where they are expelled to the atmosphere. The exhaust system also serves to dampen engine noise.

7-2. Exhaust Manifold (Fig. 7-2). The exhaust manifold connects all of the engine cylinders to the exhaust system. It usually is made of cast iron. If the exhaust manifold is formed properly, it can create a scavenging action that will cause all of the cylinders to help each other get rid of exhaust gases. Back pressure (the force that the pistons must exert to push out the exhaust gases) can be reduced by making the manifold with smooth walls and without sharp bends. All of these factors are taken into consideration when the exhaust manifold is designed and the best possible manifold is manufactured to fit into the confines of the engine compartment.

7-3. Manifold Heat Control Valve (Fig. 7-3). A valve is placed in the exhaust manifold on some gasoline engines to deflect exhaust gases toward a hot spot in the intake manifold until the engine reaches operating temperature. This valve, whose purpose is described in paragraph 4-5, is a flat metal plate that is the same shape as the opening that it controls. It pivots on a shaft and is operated by a thermostatic coil spring. The spring pulls the valve closed against a counterweight before warmup. The spring expands as the engine warms up and the counterweight pulls the valve open.

7-4. Muffler (Fig. 7-4).

a. The muffler reduces the acoustic pressure of exhaust gases to discharge them to the atmosphere with a minimum of noise. The muffler usually is located at a point about midway in the vehicle with the exhaust pipe between it and the exhaust manifold and the tailpipe leading from it to the rear of the vehicle.

b. The inlet and the outlet of the muffler usually are slightly larger than their connecting pipes so that it may hook up by slipping over them. The muffler then is secured to the exhaust pipe and the tailpipe by clamps.

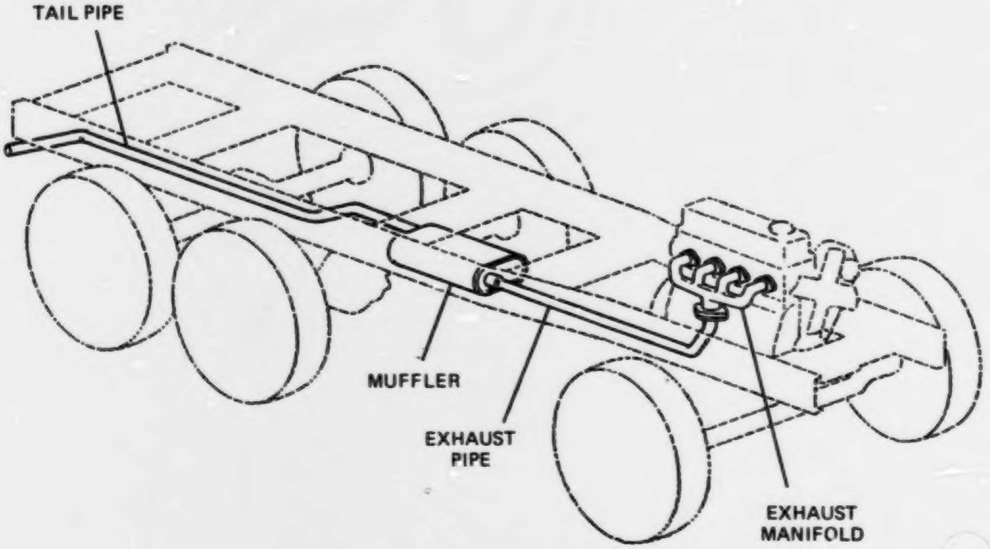


Figure 7-1. Typical Exhaust System.

TA233469

176

BEST COPY AVAILABLE

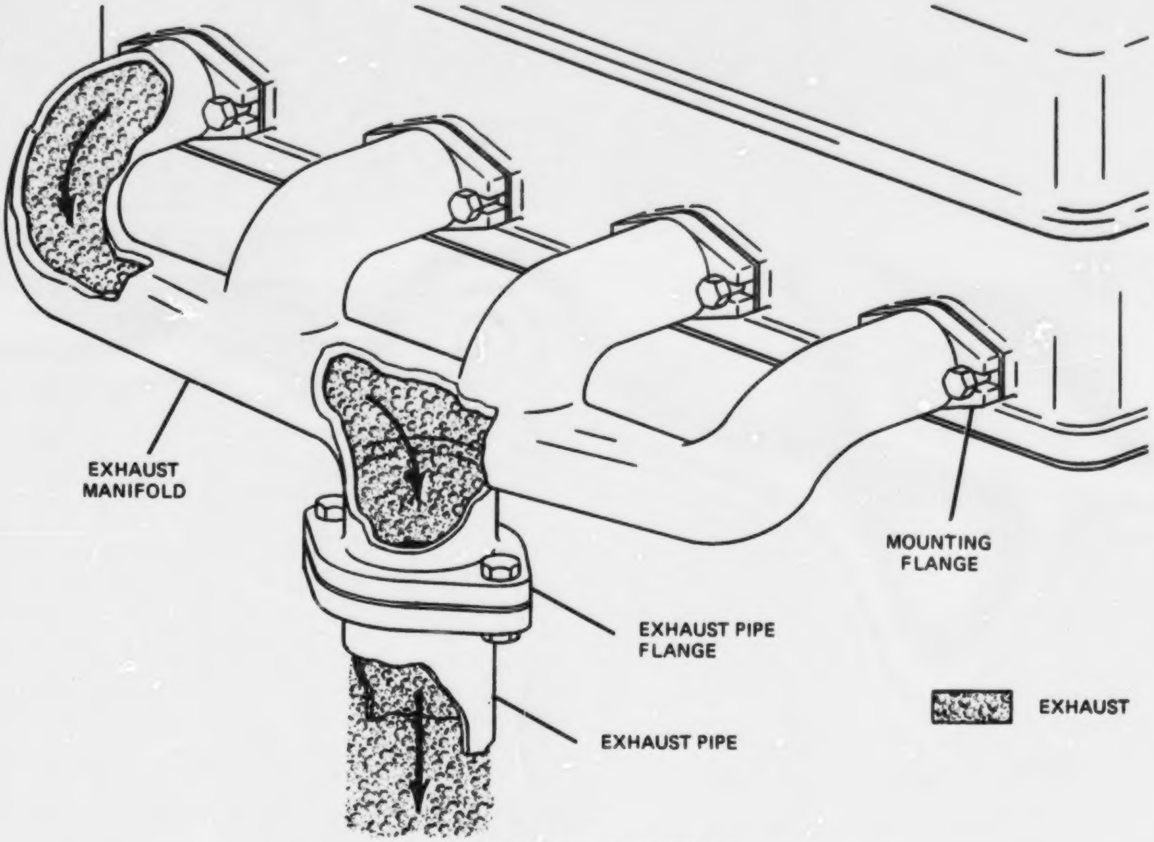


Figure 7-2. Exhaust Manifold.

c. A typical muffler has several concentric chambers with openings between them. The gas enters the inner chamber and expands as it works its way through a series of holes in the other chambers and finally to the atmosphere.

d. Mufflers must be designed to quiet exhaust noise while creating a minimum of back pressure. This could cause loss of engine power and economy and also cause overheating.

e. Exhaust system components usually are made of steel. They usually are coated with aluminum or zinc to retard corrosion. Stainless steel also is used in exhaust systems in limited quantities due to its high cost. A stainless steel exhaust system will last indefinitely.

Section II. EMISSION CONTROL SYSTEMS

7-5. Purpose (Fig. 7-5). When the fuel is burned in the combustion chamber, the ideal situation would be to have the fuel combine completely with the oxygen from the intake air. The carbon would then combine to form carbon dioxide (CO_2), the hydrogen would combine to form water (H_2O), and the nitrogen that is present in the intake air would stand alone. The only other product present in the exhaust would be any oxygen from the intake air that was not used in the burning of the fuel. In a real life situation however, this is not what happens. The fuel never combines completely with the oxygen and undesirable exhaust emissions are created as a result. The major pollutants are:

a. Carbon Monoxide (CO). Carbon monoxide is formed as a result of insufficient oxygen in the combustion mixture and combustion chamber temperatures that are too low. Carbon monoxide is a colorless, odorless gas that is poisonous.

TA233470

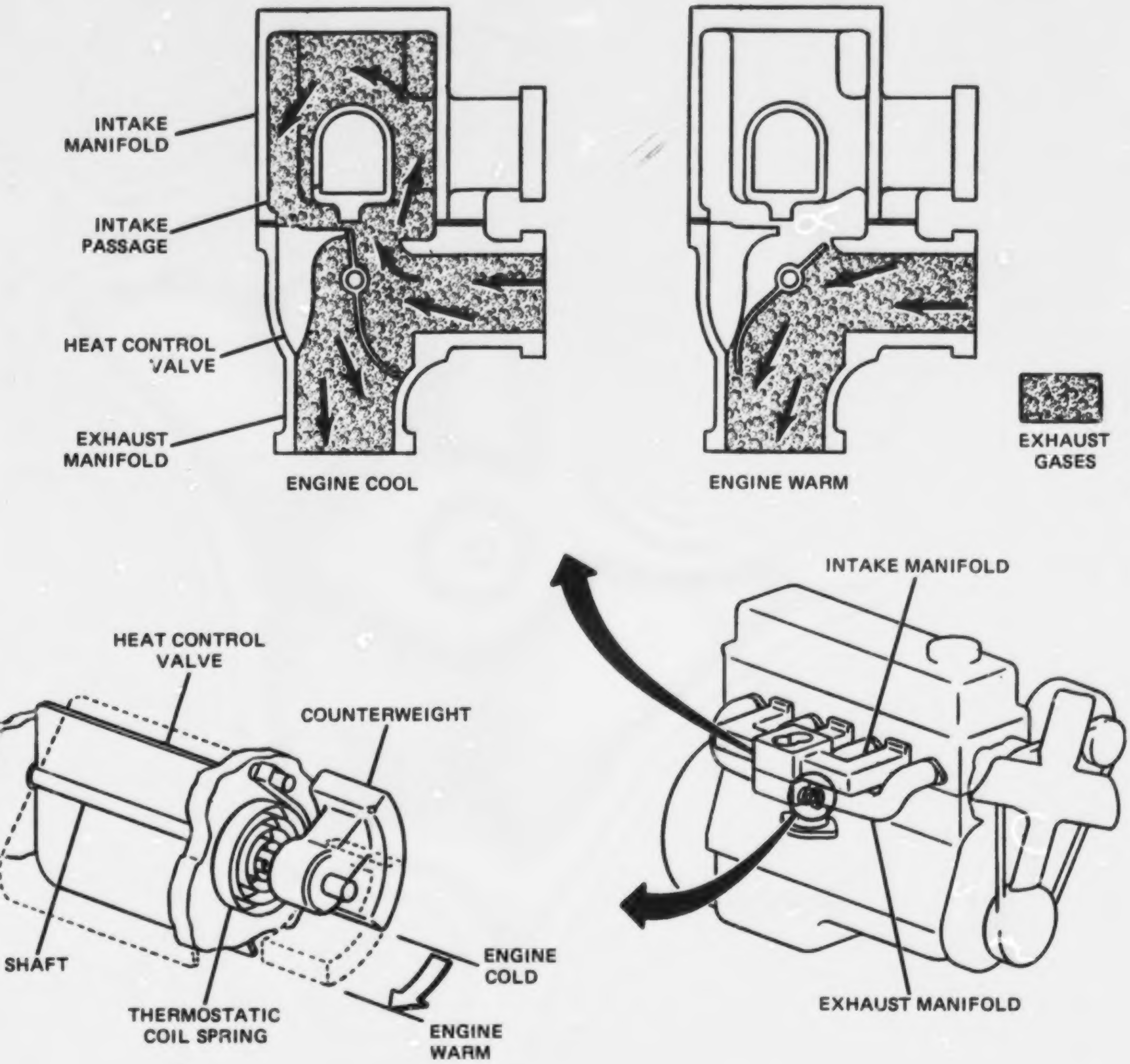

INTAKE MANIFOLD
INTAKE PASSAGE
HEAT CONTROL VALVE
EXHAUST MANIFOLD
ENGINE COOL
ENGINE WARM
EXHAUST GASES
INTAKE MANIFOLD
HEAT CONTROL VALVE
COUNTERWEIGHT
SHAFT
THERMOSTATIC COIL SPRING
ENGINE COLD
ENGINE WARM
EXHAUST MANIFOLD

Figure 7-3. Manifold Heat Control Valve.

b. Hydrocarbons (HC). Hydrocarbons are unburned fuel. They are particulate in form (solid) and, like carbon monoxide, they are manufactured by insufficient oxygen in the combustion mixture and combustion chamber temperatures that are too low. Hydrocarbons are harmful to all living things. In any urban area where vehicular traffic is heavy, hydrocarbons in heavy concentrations react with sunlight to produce a brown fog known as photochemical smog.

c. Oxides of Nitrogen (NO_x). Oxides of nitrogen are formed when the nitrogen and oxygen in the intake air combine when subjected to the high temperatures of combustion. Oxides of nitrogen are harmful to all living things.

7-6. Controlling of Exhaust Emissions. The control of exhaust emissions is a very difficult job. To eliminate carbon monoxide and hydrocarbon emissions, the temperatures of the combustion chamber would have to be raised to a point that would melt pistons and valves. This is compounded with the fact that oxides of nitrogen

TA233471

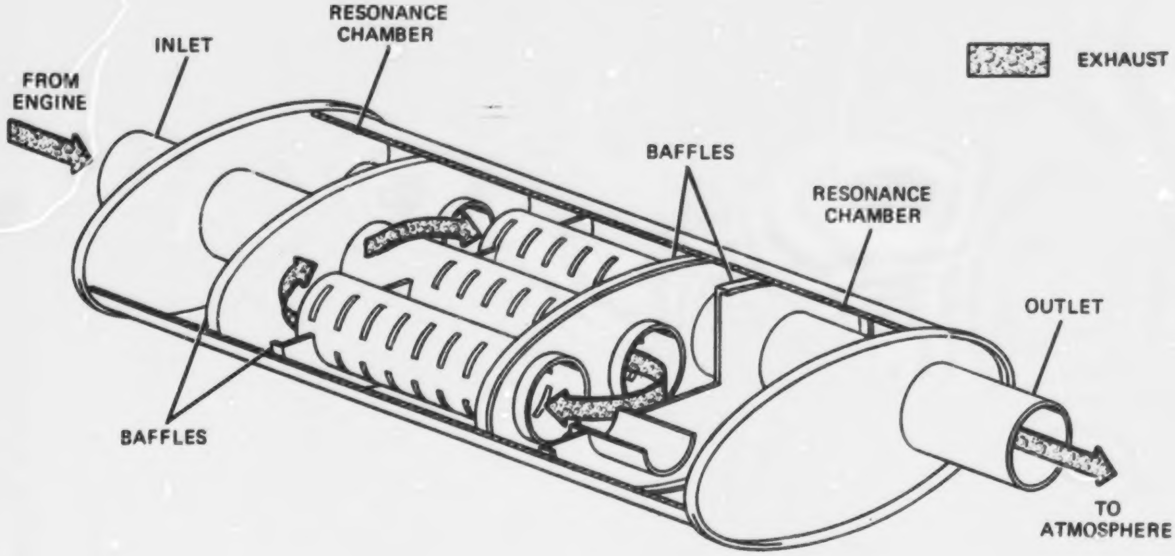

RESONANCE CHAMBER
INLET
FROM ENGINE
▨ EXHAUST
BAFFLES
RESONANCE CHAMBER
OUTLET
BAFFLES
TO ATMOSPHERE

Figure 7-4. Muffler.

emissions go up with any increases in combustion chamber temperatures. Knowing these facts, it can be seen that auxiliary emission control devices are necessary.

7-7. Crankcase Ventilation Controls. Any piston engine creates blowby (para 3-6) as it operates. The pressure created in the crankcase by blowby must be relieved by venting.

a. Draft Tube System (Fig. 7-6). Older vehicles used a very simple system that vented blowby to the atmosphere through a draft tube. The draft tube extends from an area of the crankcase that is above oil level to a point of exit that projects straight downward under the vehicle. The outlet of the tube is cut on a slant upward toward the rear of the vehicle. With this shape outlet, a suction is created by the forward

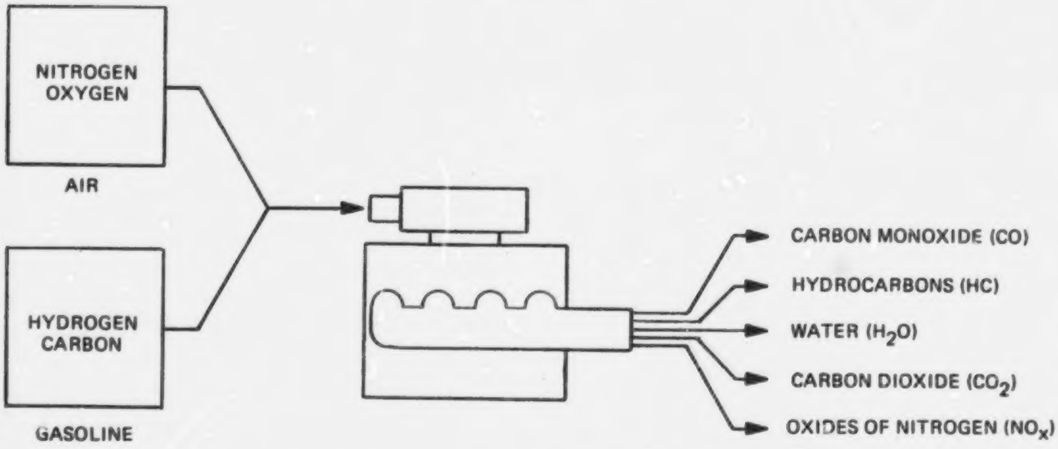

NITROGEN OXYGEN
AIR
HYDROGEN CARBON
GASOLINE
CARBON MONOXIDE (CO)
HYDROCARBONS (HC)
WATER (H_2O)
CARBON DIOXIDE (CO_2)
OXIDES OF NITROGEN (NO_x)

Figure 7-5. Vehicle Emissions.

TA233472

179

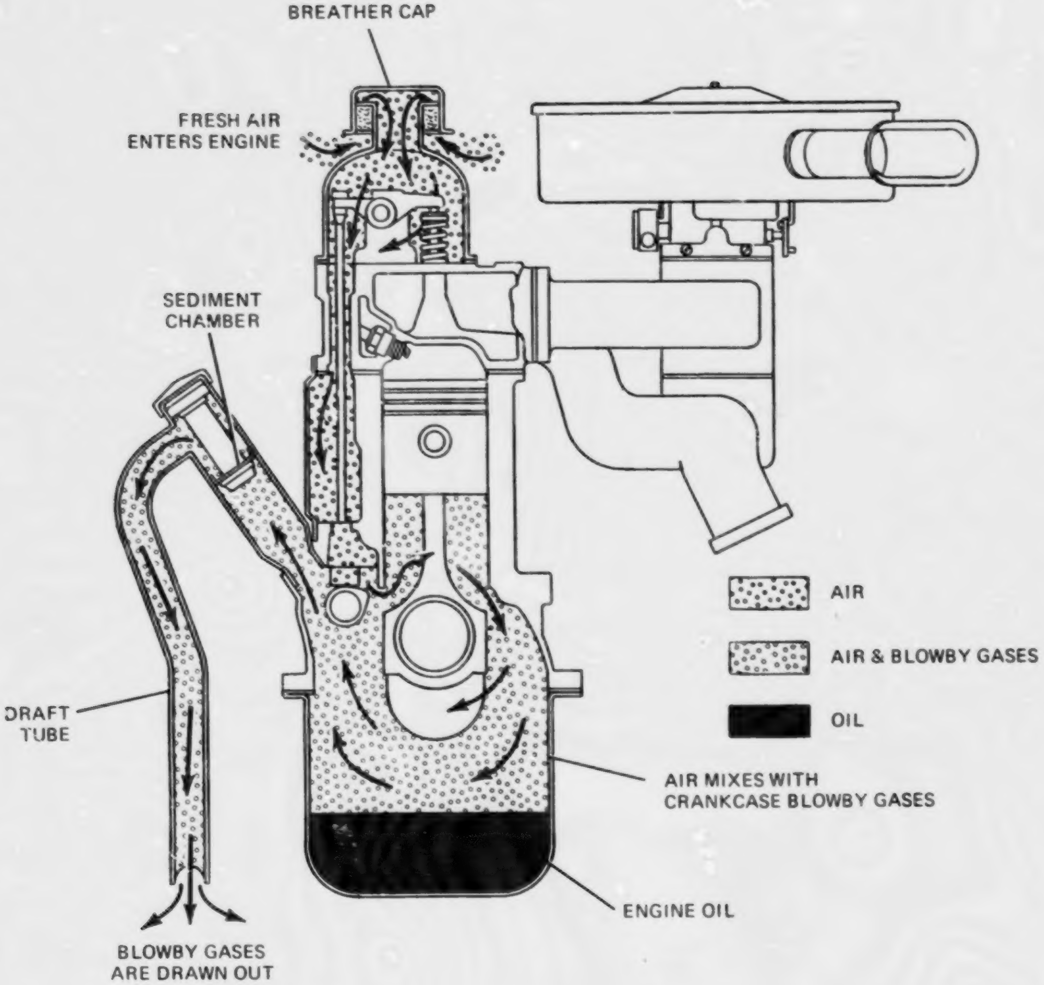

BREATHER CAP
FRESH AIR ENTERS ENGINE
SEDIMENT CHAMBER
DRAFT TUBE
BLOWBY GASES ARE DRAWN OUT
AIR
AIR & BLOWBY GASES
OIL
AIR MIXES WITH CRANKCASE BLOWBY GASES
ENGINE OIL

Figure 7-6. Draft Tube System.

movement of the vehicle. Circulation of fresh air will occur in the crankcase with the addition of a breather cap also located at a point on the crankcase above oil level.

(1) The negative pressure created at the end of the draft tube will cause air to be drawn in through the crankcase breather. A wire mesh filter is built into the breather to keep dirt out of the crankcase.

(2) The draft tube contains a sediment chamber and a wire mesh filter at the point where it attaches to the crankcase. Its purpose is to trap any oil that tries to leave through the draft tube and return it to the crankcase.

(3) By strategic location of the breather cap and draft tube and the use of baffles, a complete purging of crankcase blowby fumes is ensured.

The draft tube system is obsolete now because it discharged excessive hydrocarbon emissions directly into the atmosphere. It also did not keep the crankcase as clean as the positive crankcase ventilation system described in the next subparagraph. This is because it relied on the movement of the vehicle to activate it. As a result of this, draft tube-equipped engines were very prone to sludge buildup.

b. Positive Crankcase Ventilation (PCV) System (Fig. 7-7). The positive crankcase ventilation system utilizes manifold vacuum to purge the

TA233473

180

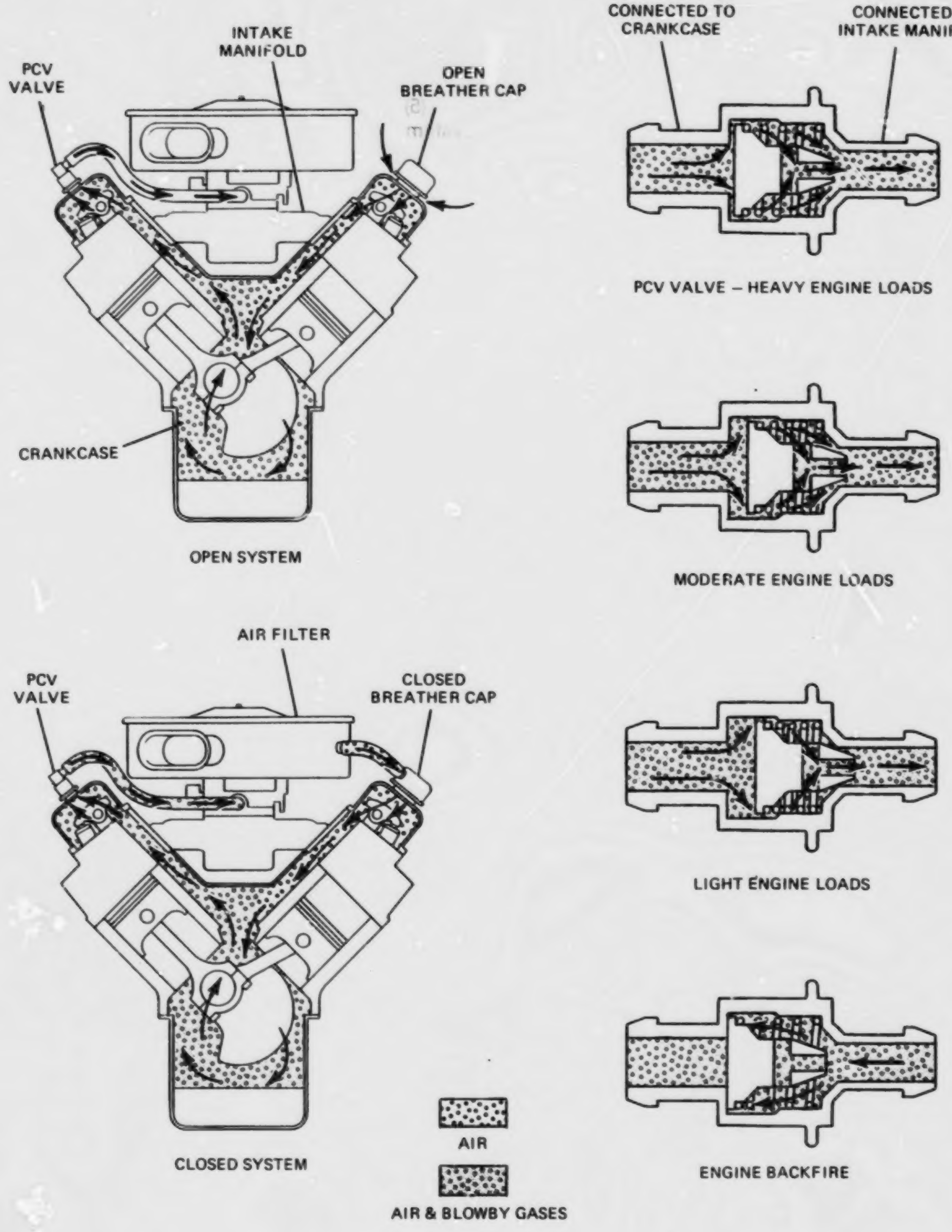

PCV VALVE
INTAKE MANIFOLD
OPEN BREATHER CAP
CRANKCASE
OPEN SYSTEM
CONNECTED TO CRANKCASE
CONNECTED TO INTAKE MANIFOLD
PCV VALVE – HEAVY ENGINE LOADS
MODERATE ENGINE LOADS
AIR FILTER
PCV VALVE
CLOSED BREATHER CAP
LIGHT ENGINE LOADS
CLOSED SYSTEM
AIR
AIR & BLOWBY GASES
ENGINE BACKFIRE

Figure 7-7. PCV System.

TA233474

crankcase of blowby fumes. The fumes are then aspirated back into the engine where they are reburned.

(1) A hose is tapped into the crankcase at a point that is well above the engine oil level. The other end of the hose is tapped into the intake manifold or the base of the carburetor. It should be noted that if the hose is tapped into the carburetor base, it will be in a location that is between the throttle valves and the intake manifold so that it will receive manifold vacuum.

(2) An inlet breather is installed on the crankcase in a location that is well above the level of the engine oil. The inlet breather also is located strategically to ensure complete purging of the crankcase by fresh air.

(3) The areas of the crankcase where the vacuum hose and the inlet breather are tapped have baffles to keep the motor oil from leaving the crankcase.

(4) A flow control valve is installed in the line that connects the crankcase to the manifold vacuum. It is called a positive crankcase ventilation (PCV) valve and serves to avoid the air-fuel mixture by doing the following:

(a) Any period of large throttle opening will be accompanied by heavy engine loads. Crankcase blowby will be at its maximum during heavy engine loads. The PCV valve will react to the small amount of manifold vacuum that also is present during heavy engine loading by opening fully through the force of its control valve spring. In this way, the system provides maximum effectiveness during maximum blowby periods.

(b) Any period of small throttle opening will be accompanied by small engine loads, high manifold vacuum, and a minimum amount of crankcase blowby. During these periods, the high manifold vacuum will pull the PCV valve to its position of minimum opening. This is important to prevent an excessively lean air-fuel mixture.

(c) In the event of engine backfire (flame traveling back through the intake manifold), the reverse pressure will push the rear shoulder of the control valve against the valve body. This will seal the crankcase from the backfire, which could otherwise cause an explosion.

(5) The positive crankcase ventilation system can be the open or the closed type.

(a) The open type has an inlet breather that is open to the atmosphere. When this system is used, it is possible for a portion of the crankcase blowby to escape through the breather whenever the engine is under a sustained heavy load. This is unacceptable on later automotive equipment and, as a result, the system is no longer used.

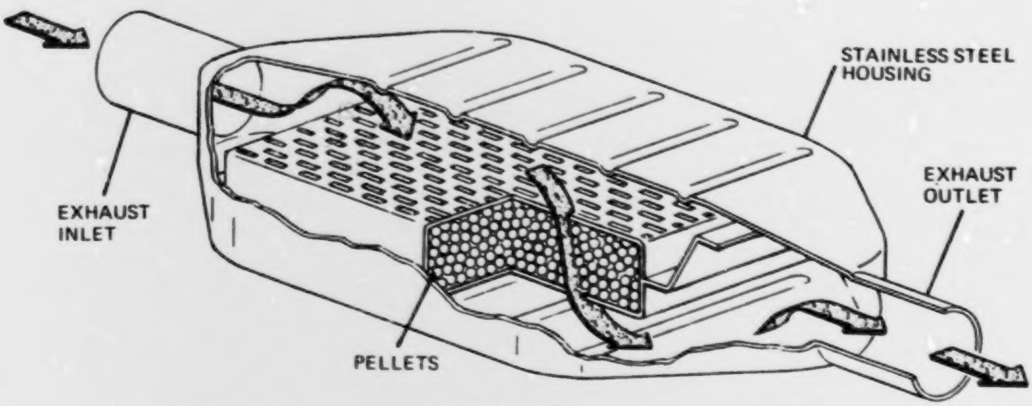
(b) The closed type has a sealed breather that is connected to the air filter by a hose. Any blowby gases that escape from the breather when this system is used will be aspirated into the carburetor and burned. This is the system that is currently used.

7-8. Catalytic Converters (Fig. 7-8).

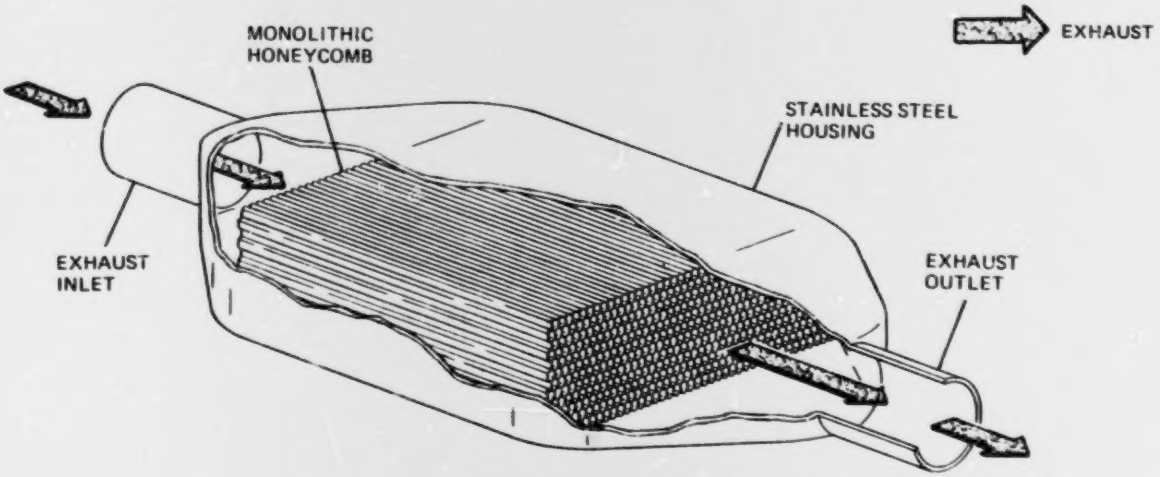
a. *Purpose.* As stated in paragraph 7-5, it is virtually impossible to keep carbon monoxide and hydrocarbon emissions at acceptable levels by controlling them in the cylinder without shortening engine life considerably. It has been found that the most practical method of controlling these emissions is outside of the engine in a device called a catalytic converter. The catalytic converter is a device that is similar in appearance to a muffler. It is positioned in the exhaust system, usually between the engine and the muffler. As the engine exhaust passes through the converter, carbon monoxide and hydrocarbons are oxidized (combined with oxygen), changing them to carbon dioxide and water.

b. *Construction and Operation.* The catalytic converter contains a material (usually platinum or palladium) that acts as a catalyst. A catalyst is something that causes a reaction between two substances without actually getting involved. In the case of the catalytic converter, oxygen is joined chemically with carbon monoxide and hydrocarbons in the presence of its catalyst.

(1) The oxidation process that occurs within the catalytic converter generates a


EXHAUST INLET
STAINLESS STEEL HOUSING
EXHAUST OUTLET
PELLETS

A. PELLET TYPE


EXHAUST
MONOLITHIC HONEYCOMB
STAINLESS STEEL HOUSING
EXHAUST INLET
EXHAUST OUTLET

B. MONOLITHIC TYPE

Figure 7-8. Catalytic Converter.

tremendous amount of heat. This causes the outer shell of the converter to operate consistently at temperatures that are several hundred degrees higher than the rest of the exhaust system. The outer shell of the catalytic converter usually is made of stainless steel to cope with these high operating temperatures.

(2) Because platinum and palladium are both very precious metals and the catalyst must have a tremendous amount of surface area in order to work properly, it has been found that the following internal structures work best for a catalytic converter.

(a) One type of converter is filled with aluminum oxide pellets that have a very thin coating of the catalytic material (A, fig. 7-8). Aluminum oxide has a very rough outer surface, giving each pellet a tremendous amount of surface area. The converter also contains baffles to ensure maximum exposure of the exhaust to the catalyst.

(b) Another type of converter uses a monolithic (one-piece) ceramic structure in a honeycomb-type form (B, fig. 7-8). The structure is coated thinly with the catalytic material. The honeycomb shape of the structure has a tremendous surface area to ensure maximum exposure of exhaust gases to the catalyst.

TA233475

c. Special Considerations. Vehicles equipped with catalytic converters require special considerations and generally are made to work in conjunction with other emission systems.

(1) The use of gasoline containing lead is destructive to a catalytic converter. In use, the lead will coat the catalyst as the exhaust passes through the converter. This will halt catalytic converter operation completely.

(2) The use of gasoline with a high sulphur content will cause considerable amounts of sulphur dioxide to be produced in the converter and emitted to the atmosphere.

(3) A heat shield must be installed between the converter and the vehicle floor because the converter can, at times, produces enough heat to ignite the interior floor covering. A heat shield also is installed under the converter to minimize the possibility of igniting objects such as grass and leaves. This is of particular importance to military vehicles during cross-country operation.

(4) An overly rich air-fuel mixture is disastrous to a catalytic converter. Excessive carbon monoxide and hydrocarbons result in such a high rate of oxidation in the converter that it can overheat to the point where its outer shell actually can melt. Because of this, the engine always must be kept in the proper state of tune.

(5) An adequate amount of oxygen must be present in the exhaust stream for the catalytic converter to operate. Therefore, a supporting system such as an air injection system (para 7-9) usually is placed on catalytic converter equipped engines to dilute the exhaust stream with fresh air.

7-9. Air Injection Systems.

a. Purpose. Air injection systems mix fresh air with the vehicle exhaust. There are two purposes for air injection systems:

(1) The exhaust gases still are burning as they are pushed out of the combustion chamber through the exhaust valve. The burning will be prolonged and intensified by injecting fresh air into the exhaust manifolds at each exhaust port. This more complete burning will reduce carbon monoxide and hydrocarbon emissions greatly.

(2) Air injection is vital to ensure an adequate supply of oxygen in the exhaust stream on vehicles equipped with catalytic converters.

b. Air Pump System (Fig. 7-9). The air pump system uses an engine-driven pump to force air into the exhaust.

(1) The pump usually is a vane-type pump that operates exactly like the vane-type oil pump (para 20-6). The pump is driven by a belt. A relief valve is built into the pump to prevent it from building too much pressure.

(2) The air from the pump is directed through rubber hoses to the air manifold. The air manifold distributes the air to each exhaust port. The point where the air is fed in may be located at the exhaust manifold or directly into the cylinder head at the exhaust port. The air is fed in through nozzles called injection tubes.

(3) A check valve is installed between the air manifold and the air pump feed hose to prevent hot exhaust from feeding back to the pump.

(4) Whenever the throttle is closed suddenly, a temporary overrich air-fuel mixture will result. The rich mixture will leave the engine with a large percentage of it unburned. When an engine is equipped with an air pump, the rich mixture will flare up and explode as it enters the exhaust and contacts the injected fresh air, resulting in a backfire condition. To correct this situation, an antibackfire valve is installed in series in the air pump feed hose. The antibackfire valve prevents the overrich mixture from occurring by injecting a short burst of air into the intake manifold whenever the throttle is released, thus preventing a backfire. Some models use a diverter valve. The diverter valve eliminates backfiring temporarily by diverting the air pump delivery to the atmosphere whenever the throttle is released suddenly, allowing the rich mixture to pass through.

c. Naturally Aspirated System (Fig. 7-10). The naturally aspirated system uses the negative pulses of the exhaust system to draw

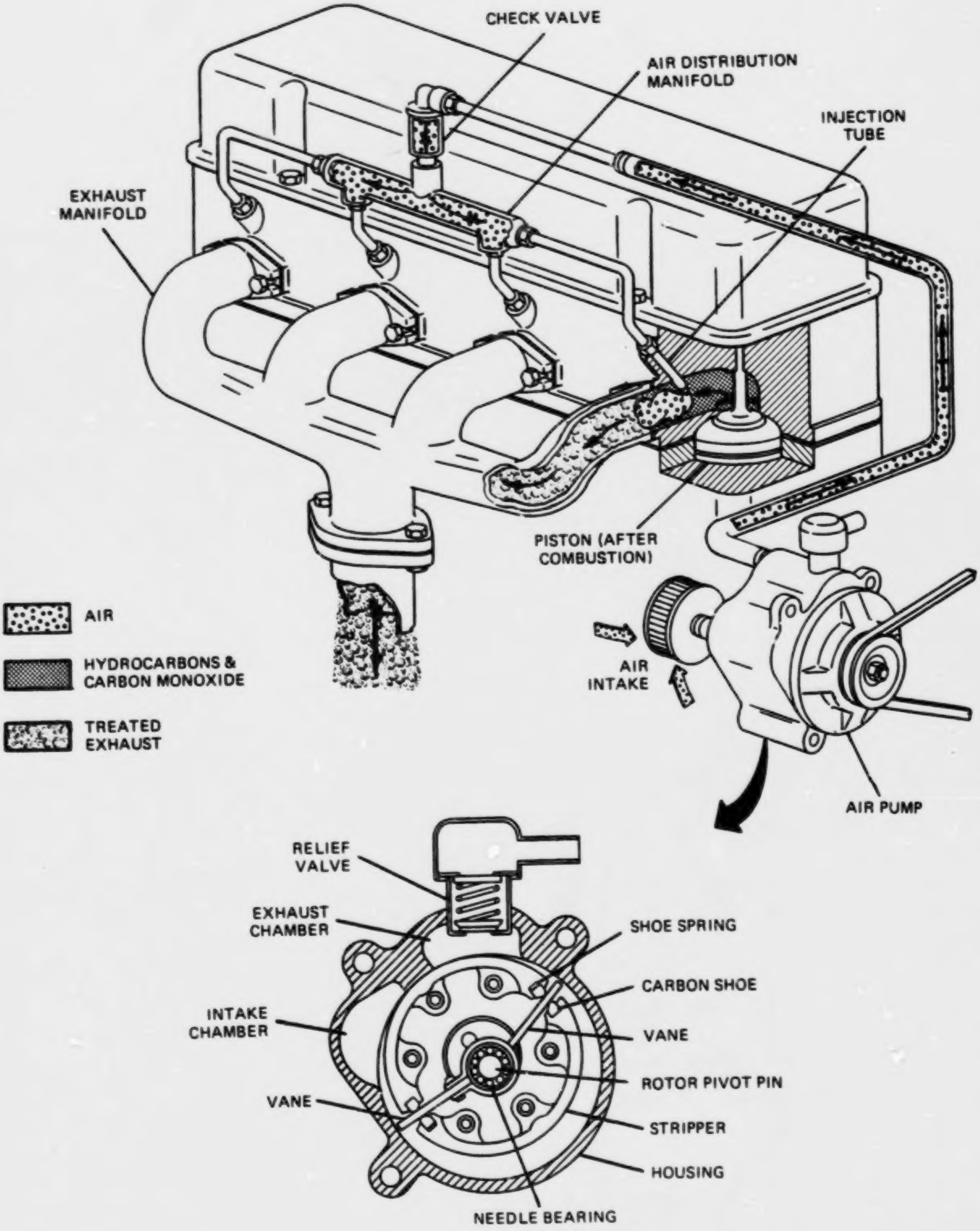

CHECK VALVE
AIR DISTRIBUTION MANIFOLD
INJECTION TUBE
EXHAUST MANIFOLD
PISTON (AFTER COMBUSTION)
AIR
HYDROCARBONS & CARBON MONOXIDE
TREATED EXHAUST
AIR INTAKE
AIR PUMP
RELIEF VALVE
EXHAUST CHAMBER
SHOE SPRING
CARBON SHOE
INTAKE CHAMBER
VANE
ROTOR PIVOT PIN
VANE
STRIPPER
HOUSING
NEEDLE BEARING

Figure 7-9. Air Pump System.

TA233476

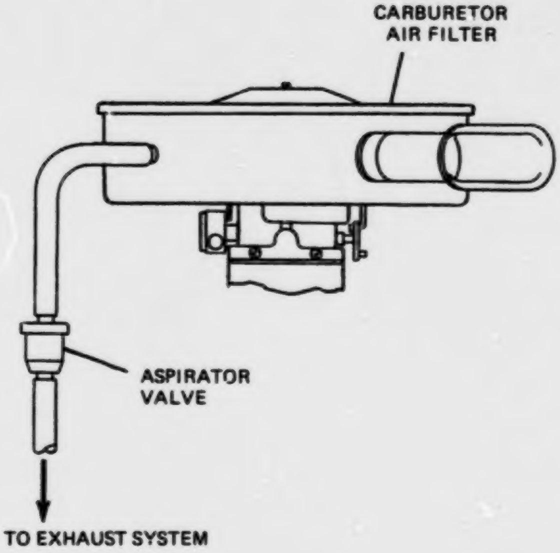


Figure 7-10. Naturally Aspirated System.

air naturally into the exhaust system. The primary purpose of this system is to provide the necessary oxygen to the catalytic converter.

(1) The key to the aspirator system is the aspirator valve. It is basically a one-way check valve that allows air to be drawn into the exhaust system during negative pulses, yet blocks the exhaust from passing out through the valve.

(2) The aspirator valve connects to the air filter housing by a rubber hose to take in air. The aspirator valve connects to the exhaust through the air manifold.

7-10. Exhaust Gas Recirculation System (Fig. 7-11).

a. Purpose. When the temperature of the combustion flame exceeds approximately 2500°F (1370°C), the nitrogen that is present in the intake air begins to combine with the oxygen to produce oxides of nitrogen (NO_x). The exhaust gas recirculation (EGR) system helps to control the formation of oxides of nitrogen by recirculating a portion of the exhaust gases back through the intake manifold, resulting in cooler combustion chamber temperatures.

b. Operation. Though there are minor differences between systems, the basic operation of an exhaust gas recirculation system is as follows:

(1) The crossover passage in the intake manifold is used as the source of exhaust gas for the system. A vacuum-operated EGR valve controls the passage of exhaust gas to the engine intake. Exhaust gas recirculation will occur whenever vacuum is applied to the valve.

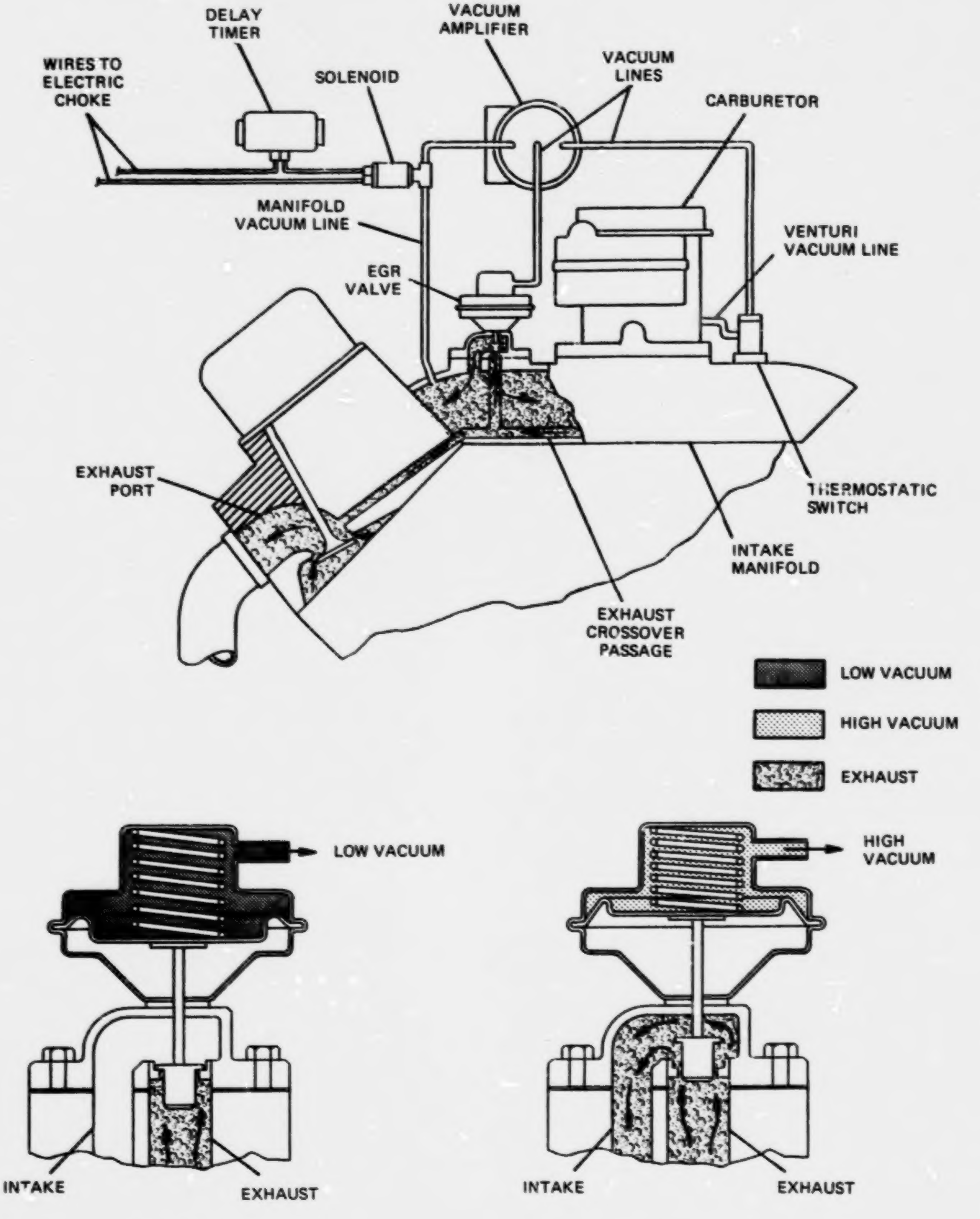
(2) The EGR valve should not be operational before the engine reaches operating temperature. If it were, it would cause extreme drivability problems. Also, there is no reason for exhaust gas recirculation before warmup because virtually no oxides of nitrogen are manufactured. The EGR valve also will not operate during periods of heavy engine loading because it would hinder performance.

(3) There are two different methods of supplying vacuum to the EGR valve.

(a) One system uses a vacuum port into the carburetor throat located just above the throttle plate. As the throttle begins to open, vacuum will begin to be applied to the port and operate the EGR valve. The valve will continue to operate fully until approximately half throttle is reached. As the throttle is open past the halfway point, exhaust gas recirculation gradually will diminish to zero as the throttle approaches the fully opened position.

(b) Another system uses a vacuum port that is directly in the carburetor venturi. This will provide vacuum for the EGR valve whenever the engine is running at high speed. The problem with using venturi vacuum is that it is not strong enough to operate the EGR valve. To make the system feasible, manifold vacuum is used to operate the EGR valve through a vacuum amplifier. The vacuum amplifier switches the manifold vacuum supply onto the EGR valve whenever venturi vacuum is applied to its signal port. At times of large engine loading (wide throttle opening), manifold vacuum will be weak, producing the desired condition of no exhaust gas recirculation.

(4) A switch that uses coolant temperature as an indicator is used to block vacuum to the EGR valve before the engine reaches operating temperature. This valve is used with all systems.


DELAY TIMER
VACUUM AMPLIFIER
WIRES TO ELECTRIC CHOKE
SOLENOID
VACUUM LINES
CARBURETOR
MANIFOLD VACUUM LINE
VENTURI VACUUM LINE
EGR VALVE
EXHAUST PORT
THERMOSTATIC SWITCH
INTAKE MANIFOLD
EXHAUST CROSSOVER PASSAGE
LOW VACUUM
HIGH VACUUM
EXHAUST
LOW VACUUM
HIGH VACUUM
INTAKE
EXHAUST
INTAKE
EXHAUST

VALVE CLOSED

VALVE OPEN

Figure 7-11. EGR System.

TA233478

7-11. Fuel Evaporation Control System (Fig. 7-12).

a. Purpose. Gasoline evaporation is a major source of hydrocarbon emissions in automotive equipment. Gasoline, because it is very volatile, evaporates in the fuel tank and the carburetor float bowl. The vaporized fuel must be vented. On uncontrolled vehicles, fuel vapor is vented to the atmosphere through the gas cap and the idle vent (para 4-14). The discharge of these vapors to the atmosphere no longer is acceptable on automotive vehicles. As a result, all currently produced vehicles are equipped with a fuel evaporation control system.

b. Construction and Operation. The fuel evaporation control system is integrated to control fuel tank and carburetor evaporation together.

(1) A charcoal-filled canister is used to store gasoline vapors. The fuel tank and the idle vent are connected to the canister. Any evaporation that occurs during periods of vehicle shutdown is collected in the canister and stored in the charcoal.

(2) A purge line connects the canister to the carburetor through a vacuum port. The port is tapped into the carburetor throat just above the throttle valve.

(3) The bottom of the charcoal canister is open. The opening is covered by a fiberglass filter.

(4) Fuel vapors that are stored in the canister are purged as the throttle is open after the engine is started. The vacuum at the purge line causes fresh air to enter through the bottom of the canister. The filter keeps foreign matter from entering the canister. As the air passes through the charcoal it removes the stored fuel vapors. The vapors then are drawn into the carburetor through the purge line, where they are reburned.

(5) The fuel cap is a pressure-vacuum type. Air can be drawn into the tank to occupy the space left by the gasoline as it is burned. However, it will not allow any fumes to pass out of the tank through it.

(6) A valve is installed in series in the vent line to the fuel tank. It will prevent gasoline from passing from the tank to the canister in the event of overfill or vehicle rollover.

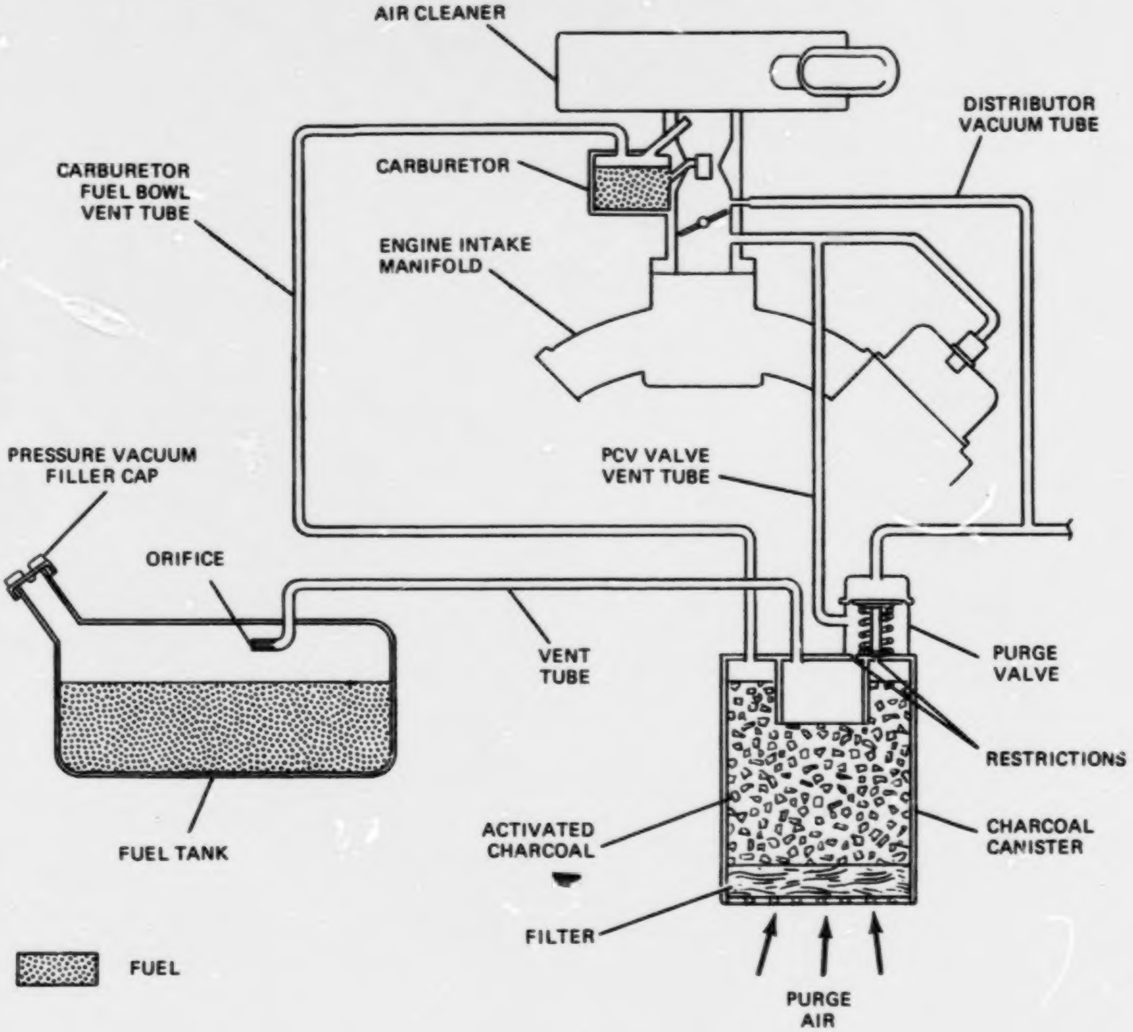

AIR CLEANER
DISTRIBUTOR VACUUM TUBE
CARBURETOR FUEL BOWL VENT TUBE
CARBURETOR
ENGINE INTAKE MANIFOLD
PRESSURE VACUUM FILLER CAP
PCV VALVE VENT TUBE
ORIFICE
VENT TUBE
PURGE VALVE
RESTRICTIONS
FUEL TANK
ACTIVATED CHARCOAL
CHARCOAL CANISTER
FILTER
FUEL
PURGE AIR

Figure 7-12. Fuel Evaporation System.

TA233479

189

BEST COPY AVAILABLE

CHAPTER 8

LUBRICATION SYSTEM

Section I. PURPOSE

8-1. General (Fig. 8-1). The lubrication system in an automotive engine supplies a constant supply of oil to all moving parts. This constant supply of fresh oil is important to minimize wear, flush bearing surfaces clean, and remove the localized heat that develops between moving parts as a result of friction. In addition, the oil that is supplied to the cylinder walls helps the piston rings make a good seal to reduce blowby (para 3-6).

8-2. Oil as a Lubricant. The primary function of engine oil is to reduce friction between moving parts (lubricate). Friction, in addition to wasting

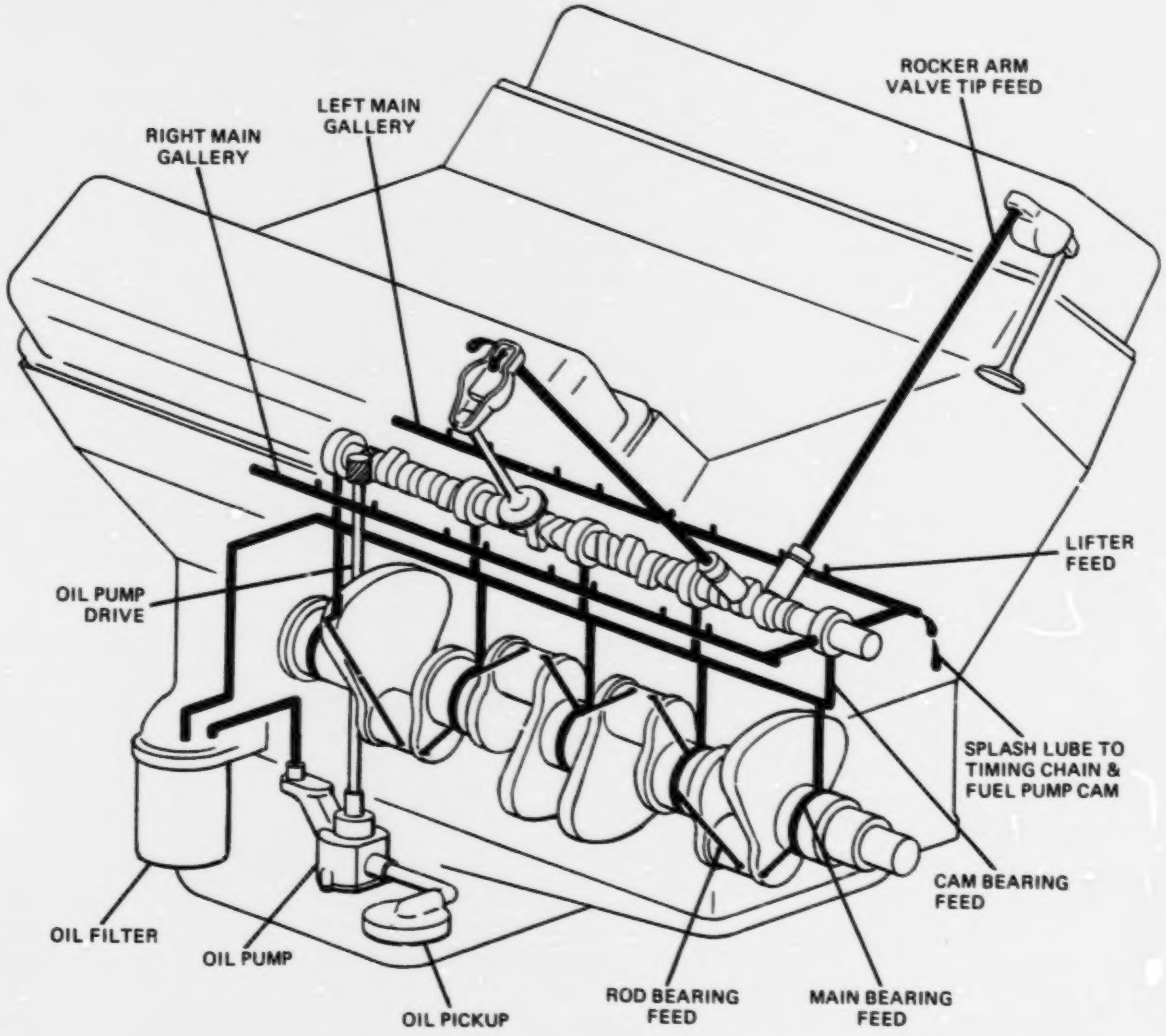

ROCKER ARM VALVE TIP FEED
LEFT MAIN GALLERY
RIGHT MAIN GALLERY
LIFTER FEED
OIL PUMP DRIVE
SPLASH LUBE TO TIMING CHAIN & FUEL PUMP CAM
CAM BEARING FEED
OIL FILTER
OIL PUMP
OIL PICKUP
ROD BEARING FEED
MAIN BEARING FEED

Figure 8-1. Typical Engine Lubrication System.

TA233480

190

engine power, creates destructive heat and rapid wear of parts. The greater the friction present between moving parts, the greater the energy required to overcome that friction. The increase in energy adds to the amount of heat generated, causing moving parts that are deprived of oil to melt, fuse, and seize after a very short period of engine operation. The effectiveness of a modern lubrication system makes possible the use of friction-type bearings (para 19-7) in an engine. Friction between the pistons and the cylinder walls is severe, making effective lubrication of this area imperative. Lubrication of the connecting rod and main bearings is crucial because of the heavy loads that are placed on them. There are many other less critical engine parts that also need a constant supply of oil, such as the camshaft, valve stems, rocker arms, and timing chains.

8-3. Oil as a Coolant. Engine oil circulated throughout the engine also serves to remove heat from the friction points. The oil circulates through the engine and drains to the sump. The heat picked up by the oil while it is circulated is removed by an airflow around the outside of the sump. In some instances where the sump is not exposed to a flow of air, it is necessary to add an oil cooling unit that transfers the heat from the oil to the engine cooling system.

Section II. ENGINE OILS

8-4. General. Mineral oil is used in most internal combustion engines. Engine oils generally are classified according to their performance qualities and their thickness.

a. How Oil Lubricates (Fig. 8-2).

(1) Every moving part of the engine is designed to have a specific clearance between it and its bearing. As oil is fed to the bearing it forms a film, preventing the rotating part from actually touching the bearing.

(2) As the part rotates, the film of oil acts as a series of rollers. Because the moving parts do not actually touch each other, friction is reduced greatly.

(3) It is important that sufficient clearance be allowed between the part and the bearing. Otherwise the film might be too thin. This would allow contact between the parts, causing the bearing to wear or burn up.

(4) It also is important that the clearance not be too large between rotating parts and their bearings. This is true particularly with heavily loaded bearings like those found on the connecting rods. The heavy loads could then cause the oil film to be squeezed out, resulting in bearing failure.

b. Oil Contamination (Fig. 8-3). Oil does not wear out but it does become contaminated. When foreign matter enters through the air intake, some of it will pass by the piston rings and enter the crankcase. This dirt, combined with foreign matter entering through the crankcase breather pipe, mixes with the oil, and when forced into the bearings, greatly accelerates wear. Water, one of the products of combustion, will seep by the piston rings as steam and condense in the crankcase. The water in the crankcase then will emulsify with the oil to form a thick sludge. Products of fuel combustion will mix with the oil as they enter the crankcase through blowby (para 3-6). The oil, when mixed with the contaminants, loses its lubricating qualities and becomes acidic. Engine oil must be changed periodically to prevent contaminated oil from allowing excessive wear and causing etching of bearings. Oil contamination is controlled in the following ways.

(1) Control engine temperature; a hotter running engine burns its fuel more completely and evaporates the water produced within it before any appreciable oil contamination occurs.

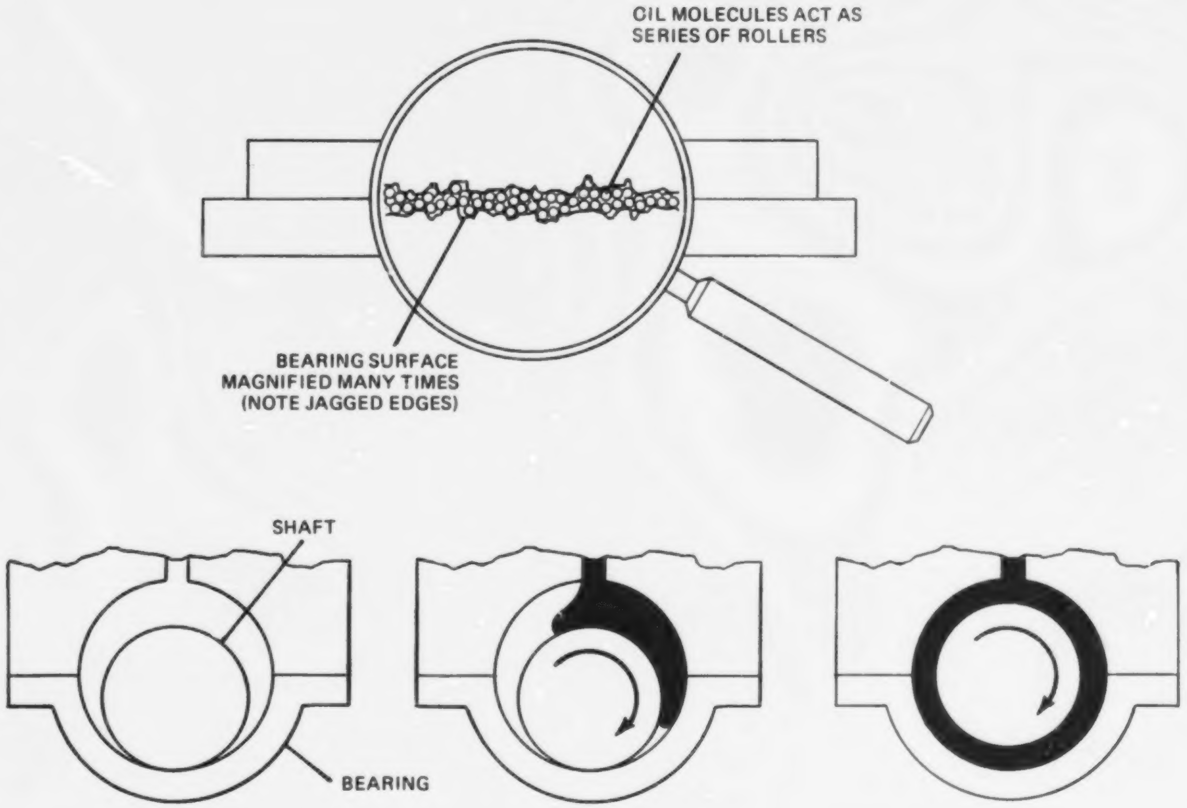
(2) The use of oil filters removes particulate matter from the oil before it reaches the bearings, minimizing wear.

(3) An adequate crankcase ventilation system will purge the crankcase of blowby fumes effectively before a large amount of contaminants can mix with the oil.

(4) The use of air intake filters trap foreign material and keep it from entering the engine.

c. Oil Dilution (Fig. 8-3). Engine oil thins out when mixed with gasoline, causing a dramatic

191


OIL MOLECULES ACT AS SERIES OF ROLLERS
BEARING SURFACE MAGNIFIED MANY TIMES (NOTE JAGGED EDGES)
SHAFT
BEARING

1. RESIDUAL OIL ONLY. SHAFT RESTING ON BEARING.

2. OIL ENTERING BEARING. SHAFT ROTATING.

3. OIL HAS WEDGED SHAFT UP. SHAFT AND BEARING WILL NOT TOUCH.

Figure 8-2. How Oil Lubricates.

drop in its lubricating qualities. Some of the causes of oil dilution are the following.

(1) Excessive use of a hand choke causes an overrich mixture and an abundance of unburned fuel to leak past the piston rings into the crankcase. The same condition can occur on vehicles equipped with an improperly adjusted or malfunctioning automatic choke system.

(2) A vehicle with a defective ignition system can cause oil dilution due to misfiring spark plugs. Whenever a spark plug misfires, the balance of the unburned fuel will be forced into the exhaust system but a small portion of it also will pass the rings and enter the crankcase.

(3) An engine with a malfunctioning thermostat (para 9-9) or an engine that is operated for short durations only will never reach a sufficient temperature to burn the fuel completely. A small amount of oil dilution occurs in all engines from initial startup through warmup. When the engine reaches its operational range (180°F (82.2°C) to 200°F (93.3°C)), however, this condition is corrected as the excess gasoline vaporizes in the crankcase and is carried off by the crankcase ventilation system.

8-5. American Petroleum Institute (API) Rating System.

a. General. The API system for rating oil classifies oil according to its performance characteristics. The higher rated oils contain additives that provide maximum protection against

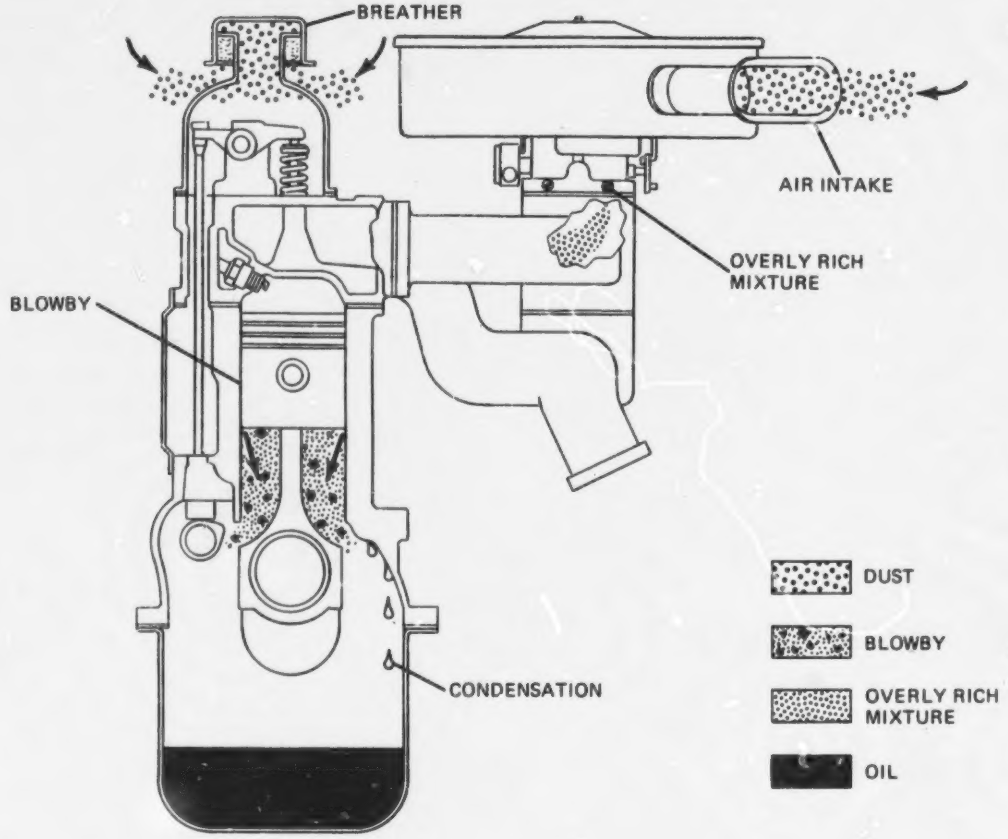


Figure 8-3. Sources of Oil Contamination.

rust, corrosion, wear, oil oxidation, and thickening at high temperatures. There are currently six oil classifications for gasoline engines (SA, SB, SC, SD, SE, and SF) and four classifications for diesel engines (CA, CB, CC, and CD). The higher the alpha designation, the higher quality the oil is.

b. API Designations.

(1) *SA (Utility Gasoline Engines).* Adequate for utility engines subjected to light loads, moderate speeds, and clean conditions. SA-rated oils generally contain no additives.

(2) *SB (Minimum Duty Gas – Automotive).* Adequate for automotive use under favorable conditions (light loads, low speeds, and moderate temperatures) with relatively short oil change intervals. SB-rated oils generally offer minimal protection to the engine against bearing scuffing, corrosion, and oil oxidation.

(3) *SC.* Meets all automotive manufacturers' requirements for vehicles manufactured from 1964 to 1967.

(4) *SD.* Meets all automotive manufacturers' requirements for vehicles manufactured from 1968 to 1970. SD oil offers additional protection over SC oils that is necessary with the introduction of emission controls.

(5) *SE.* Meets all automotive manufacturers' requirements for vehicles manufactured from 1971 to 1979. Stricter emission requirements create the need for this oil to provide protection during these years.

(6) *SF.* Meets all automotive manufacturers' requirements for vehicles manufactured

TA233482

after 1980. The SF oil is designed to meet the demands of the small, high-revving engines that are popular due to the trend toward downsizing of vehicles. An SF oil can be used in all automotive vehicles. API service ratings have related military specification designations.

8-6. Viscosity and Viscosity Measurement.

a. General. The viscosity of an oil refers to its resistance to flow. When oil is hot, it will flow more rapidly than when it is cold. In cold weather, therefore, oil should be thin (low viscosity) to permit easy flow. In hot weather, oil should be heavy (high viscosity) to permit it to retain its film strength. The ambient temperature in which a vehicle operates determines whether an engine oil of high or low viscosity should be used. If, for example, too thin an oil were used in hot weather, consumption would be high because it would leak past the piston rings easily. The lubricating film would not be heavy enough to take up bearing clearances or prevent bearing scuffing. In cold weather, heavy oil would not give adequate lubrication because its flow would be sluggish; some parts might not receive oil at all.

b. Viscosity Measurement. Oils are graded according to their viscosity by a series of Society of Automotive Engineers (SAE) numbers. The viscosity of the oil will increase progressively with the SAE number. An SAE 5 oil would be very light (low viscosity) and an SAE 90 oil would be very heavy (high viscosity). The viscosity of the oil used in gasoline engines generally ranges from SAE 5 (arctic use) to SAE 60 (desert use). It should be noted that the SAE number of the oil has nothing to do with the quality of the oil. The viscosity number of the oil is determined by heating the oil to a predetermined temperature and allowing it to flow through a precisely sized orifice while measuring the rate of flow. The faster an oil flows, the lower the viscosity. The testing device is called a viscosimeter. Any oil that meets SAE low temperature requirements will be followed by the letter W. An example would be SAE 10W.

8-7. Multiweight Oils. Multiweight oils are manufactured to be used in most climates because they meet the requirements of a light oil in cold temperatures and of a heavy oil in hot temperatures. Their viscosity rating will contain two numbers.

An example of this would be 10W-30. An oil with a viscosity rating of 10W-30 would be as thin as a 10W-weight oil at 0°F (-17.7°C) and as thick as a 30-weight oil at 210°F (99°C).

8-8. Detergent Oils. Detergent oils contain additives that help keep the engine clean by preventing the formation of sludge and gum. All SE and SF oils are detergent oils.

Section III. OIL PUMPS

8-9. General. Oil pumps are mounted either inside or outside of the crankcase, depending on the design of the engine. They usually are mounted so that they can be driven by a worm or spiral gear directly from the camshaft. Oil pumps generally are of the gear or the rotor type.

8-10. Rotor-Type Oil Pump (Fig. 8-4). Refer to paragraph 5-21 for the operation of a rotor-type oil pump.

8-11. Gear-Type Oil Pump (Fig. 8-5). Refer to paragraph 5-23 for the operation of a gear-type oil pump.

8-12. Oil Strainer and Pickup (Fig. 8-6). Most manufacturers of in-line and V-type engines place at least one oil strainer or screen in the lubrication system. The screen usually is a fine mesh bronze screen that is located in the oil sump on the end of the oil pickup tube. The oil pickup tube then is threaded directly into the pump inlet or may attach to the pump by a bolted flange. A fixed-type strainer, like the one described, is located so that a constant supply of oil will be assured. Some automotive engines use a pickup that is hinged from the oil pump. The pickup is designed to float on top of the oil, thus preventing sediment from being drawn into the oiling system.

8-13. Oil Filters.

a. General (Fig. 8-7). The oil filter removes most of the impurities that have been picked up by the oil as it is circulated through the engine. The

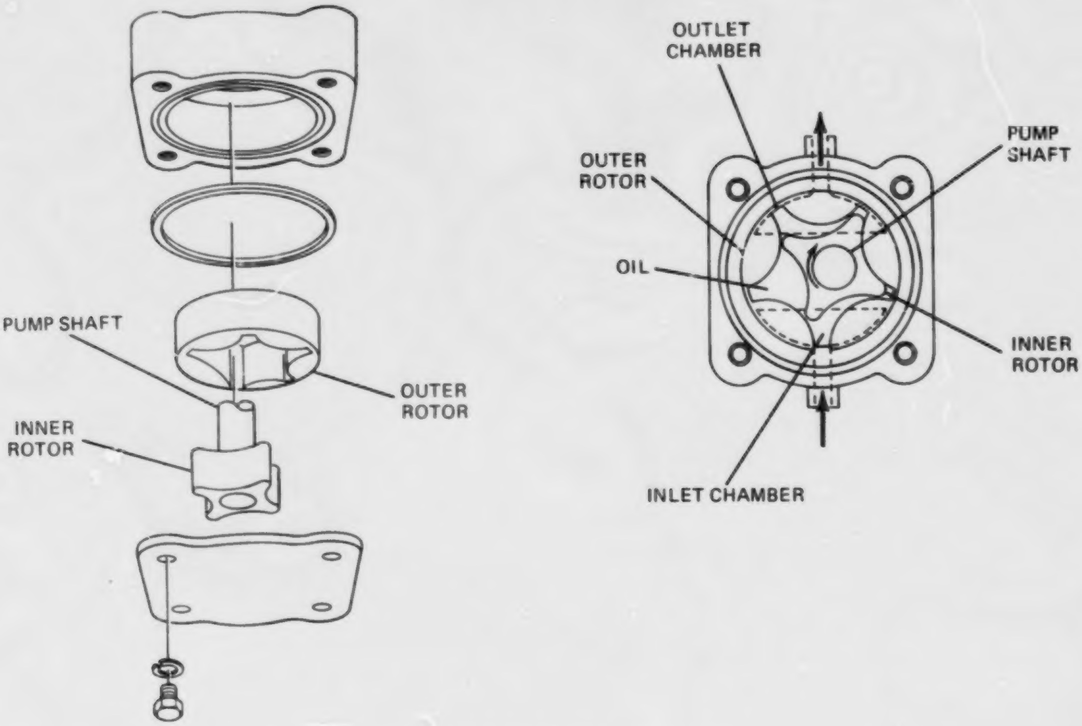

PUMP SHAFT
OUTER ROTOR
INNER ROTOR
OUTLET CHAMBER
OUTER ROTOR
PUMP SHAFT
OIL
INNER ROTOR
INLET CHAMBER

Figure 8-4. Rotor-Type Oil Pump.

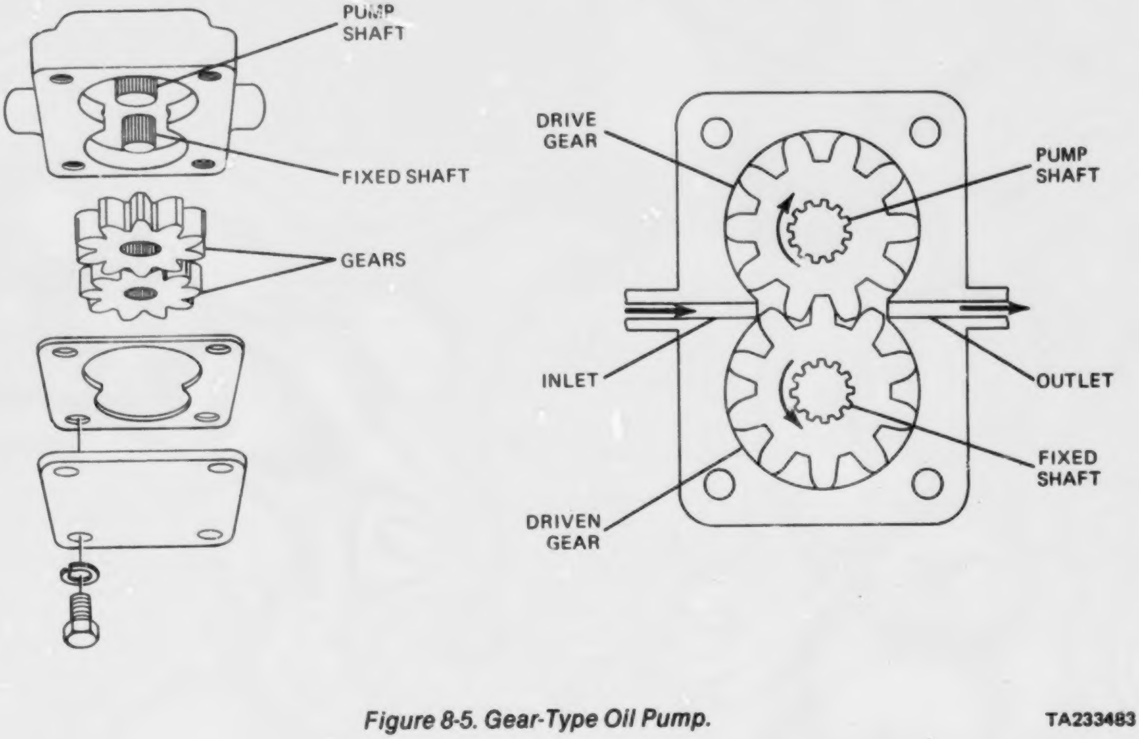

PUMP SHAFT
FIXED SHAFT
GEARS
DRIVE GEAR
PUMP SHAFT
INLET
OUTLET
FIXED SHAFT
DRIVEN GEAR

Figure 8-5. Gear-Type Oil Pump.

TA233483

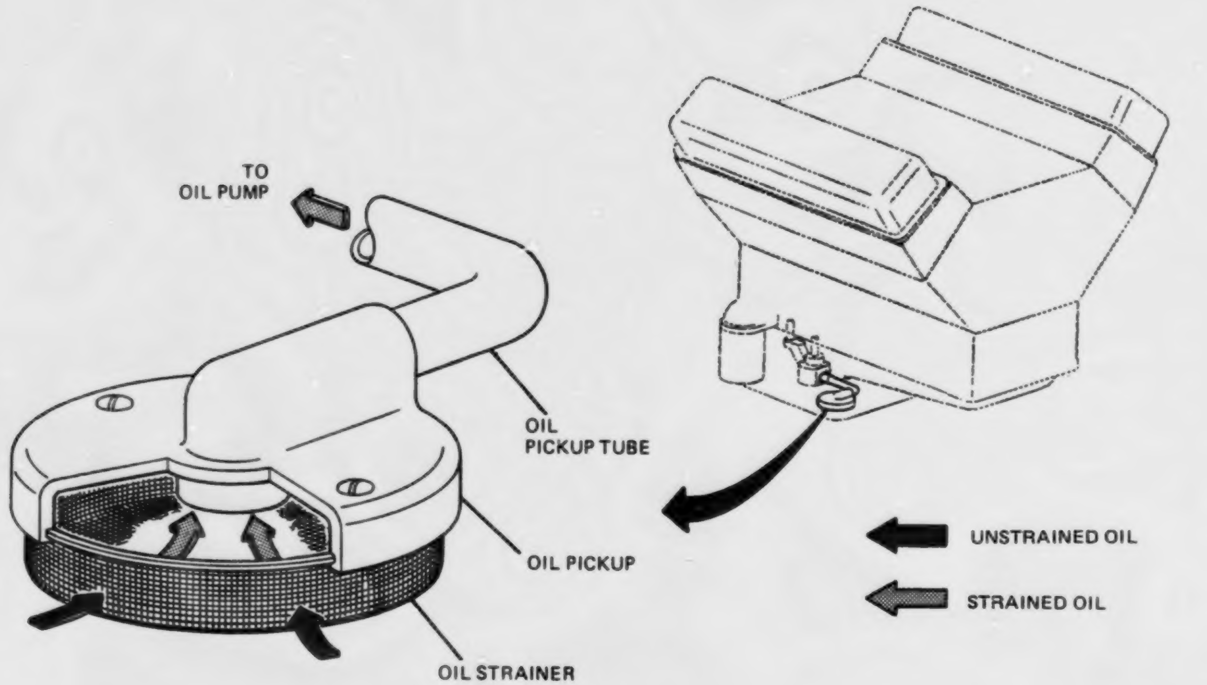


Figure 8-6. Oil Pickup and Strainer.

filter is mounted outside of the engine and is designed to be replaceable readily.

b. Filter Configurations (Fig. 8-7). There are two basic filter element configurations: the cartridge type and the sealed can type.

(1) The cartridge-type filter element fits into a permanent metal container. Oil is pumped under pressure into the container, where it passes from the outside of the filter element to the center. From here the oil exits the container. The element is changed easily by removing the cover from the container when this type of filter is used.

(2) The sealed can-type filter element is completely self-contained, consisting of an integral metal container and filter element. Oil is pumped into the container on the outside of the filter element. The oil then passes through the filter medium to the center of the element, where it exits the container. This type of filter is screwed onto its base and is removed by spinning it off.

c. Filter Medium Materials (Fig. 8-8).

(1) Cotton waste or resin-treated paper are the two most popular automotive filter mediums. They are held in place by sandwiching them between two perforated metal sheets.

(2) Some heavy-duty applications use layers of metal that are thinly spaced apart. Foreign matter is strained out as the oil passes between the metal layers.

d. Filter System Configurations. There are two filter system configurations. These are the full-flow system and the bypass system. Operation of each system is as follows:

(1) The full-flow system (A, fig. 8-9) is the most popular in current automotive design. All oil in a full-flow system is circulated through the filter before it reaches the engine. When a full-flow system is used, it is necessary to incorporate a bypass valve in the oil filter to allow the oil to circulate through the system without passing through the element in the event that it becomes clogged. This will prevent the oil supply from being cut off to the engine.

(2) The bypass system (B. fig. 8-9) diverts only a small quantity of the oil each time it is

TA233484

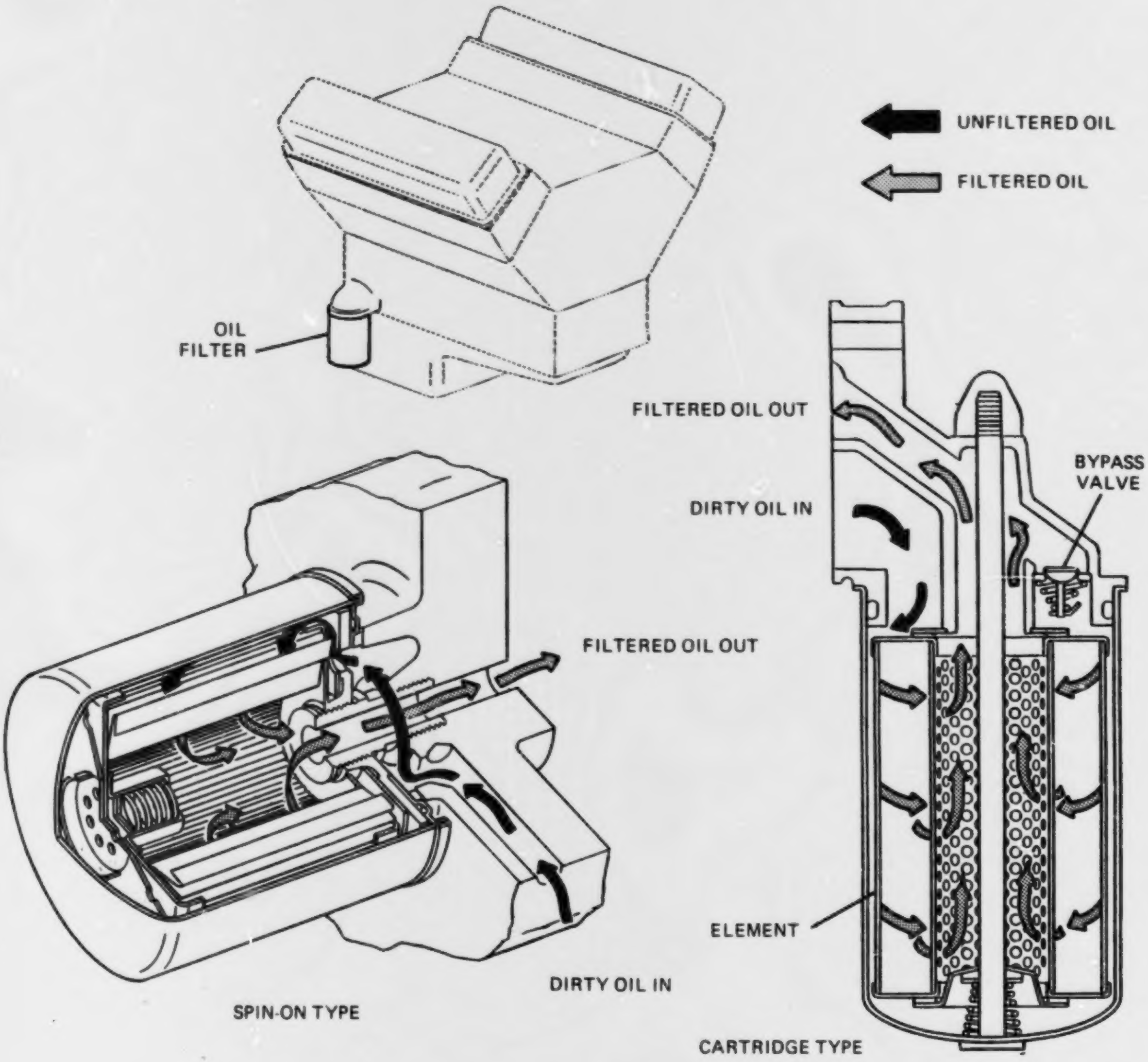

UNFILTERED OIL
FILTERED OIL
OIL FILTER
FILTERED OIL OUT
DIRTY OIL IN
BYPASS VALVE
FILTERED OIL OUT
ELEMENT
DIRTY OIL IN
SPIN-ON TYPE
CARTRIDGE TYPE

Figure 8-7. Oil Filters.

circulated and returns it directly to the oil pan after it is filtered. This type of system does not filter the oil before it is sent to the engine.

8-14. Oil Coolers.

a. Purpose. Some automotive configurations do not allow sufficient airflow around the crankcase to allow the oil to dissipate heat. Engines in heavy duty and desert use must be able to dissipate more heat from their oil than normal airflow is able to. An oil cooler is installed in all of these cases.

b. Oil Temperature Regulator (Fig. 8-10). The oil temperature regulator is used to prevent the oil temperature from rising too high in hot weather and to assist in raising the temperature during cold starts in winter weather. The regulator makes use of the liquid in the cooling system. It provides a more positive means of controlling oil temperature than does cooling by radiation of heat from the oil pan wells. The regulator unit is made up of a core and a housing. The core through which the oil circulates is of cellular or bellows construction, and is built to expose as much oil as possible to the coolant that circulates

TA233485

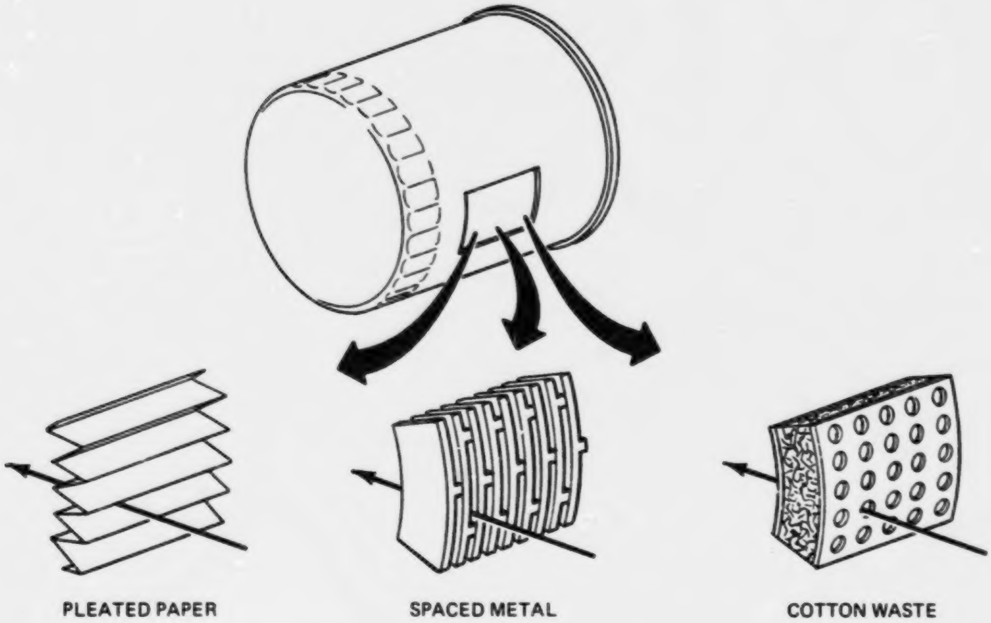


Figure 8-8. Oil Filtering Mediums.

through the housing. The regulator is attached to the engine so that the oil will flow through the regulator after passing through the pump. The oil leaves the regulator either heated or cooled, depending on the temperature of the coolant, and then is circulated through the engine.

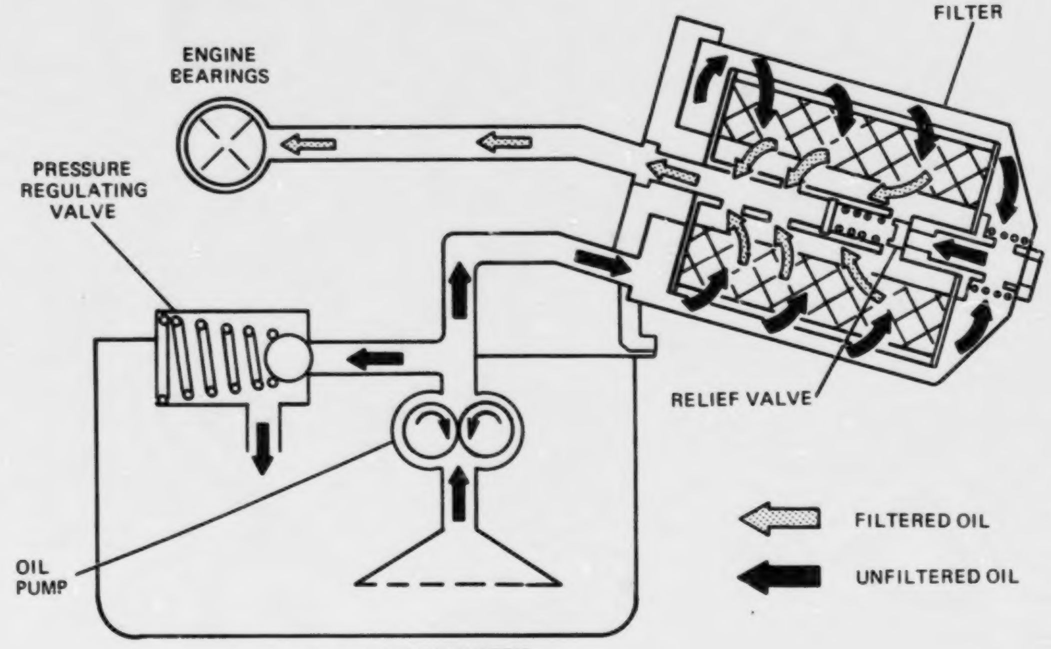
c. Oil Cooler (Fig. 8-11). The types of oil coolers used with combat vehicles consist of a radiator through which air is circulated by movement of the vehicle, or by a cooling fan. Oil from the engine is circulated through this radiator and back to the sump or supply tank. The radiator will act to cool the oil only in this system. It will not heat oil in a cold engine.

8-15. Oil Level Indicator (Fig. 8-12). The oil level indicator is usually a bayonet type. It consists of a small rod, known as a dipstick, that extends through a tube into the crankcase. It is marked to show when the crankcase is full or, if it is low, how much oil is needed. Readings are taken by pulling the dipstick out and noting how high the level is on it.

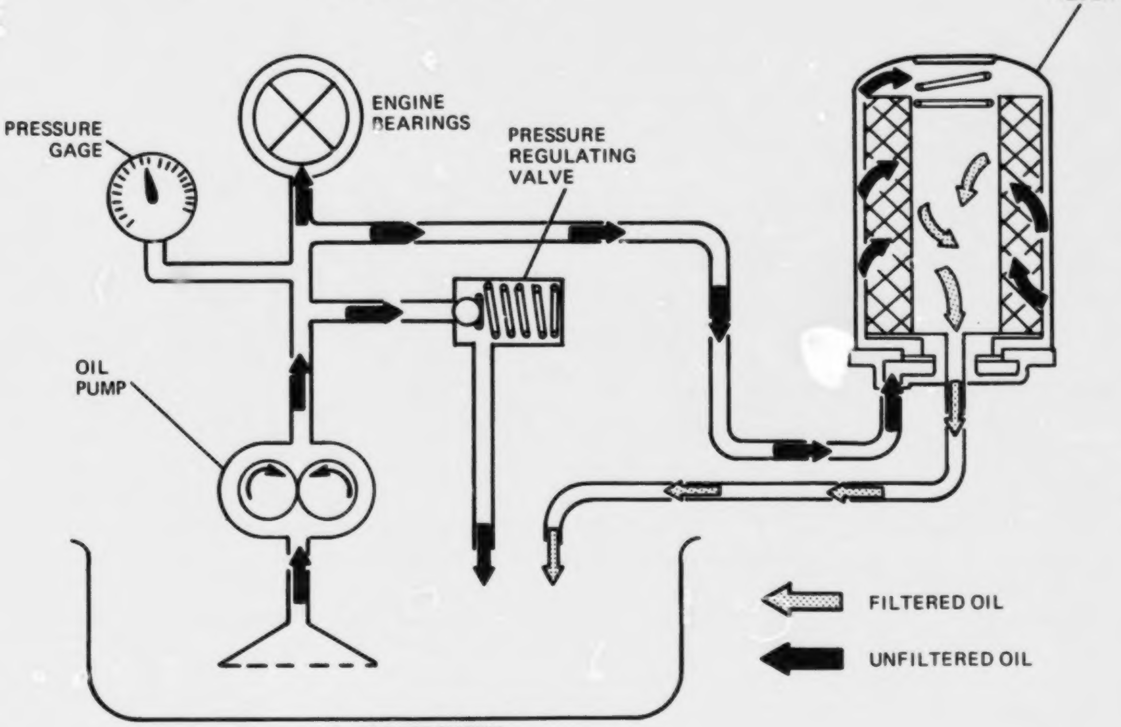
8-16. Pressure Regulator (Fig. 8-13). The oil pump will produce pressures in great excess to those necessary. This excess pressure, if uncontrolled, would cause excess oil consumption due to flooded cylinder walls and leakage through oil seals. A spring-loaded regulator valve is installed in the lubrication system to control pump pressure. The valve will open as the pressure reaches the value that is determined by the spring, causing excess oil to be diverted back to the crankcase.

TA233486

198


FILTER
ENGINE BEARINGS
PRESSURE REGULATING VALVE
RELIEF VALVE
OIL PUMP
FILTERED OIL
UNFILTERED OIL

A. FULL-FLOW SYSTEM


FILTER
ENGINE BEARINGS
PRESSURE GAGE
PRESSURE REGULATING VALVE
OIL PUMP
FILTERED OIL
UNFILTERED OIL

B. BYPASS SYTEM

Figure 8-9. Filter System Configurations.

TA233487

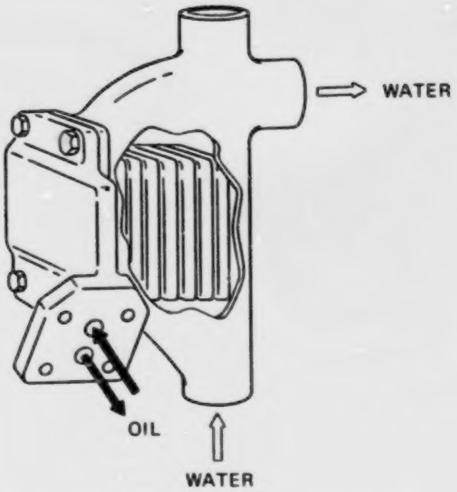

WATER
OIL
WATER

Figure 8-10. Oil Temperature Regulator.

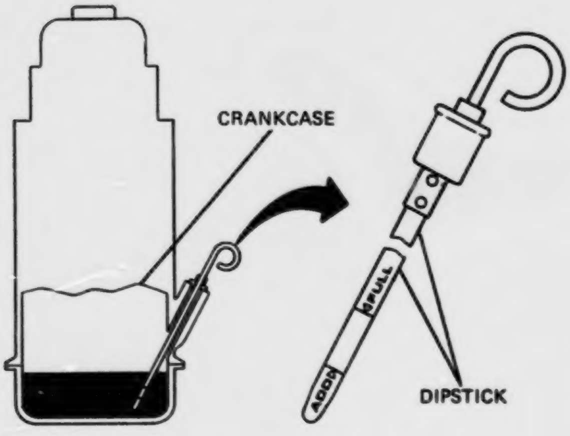

CRANKCASE
ADD
FULL
DIPSTICK

Figure 8-12. Oil Level Indicator.

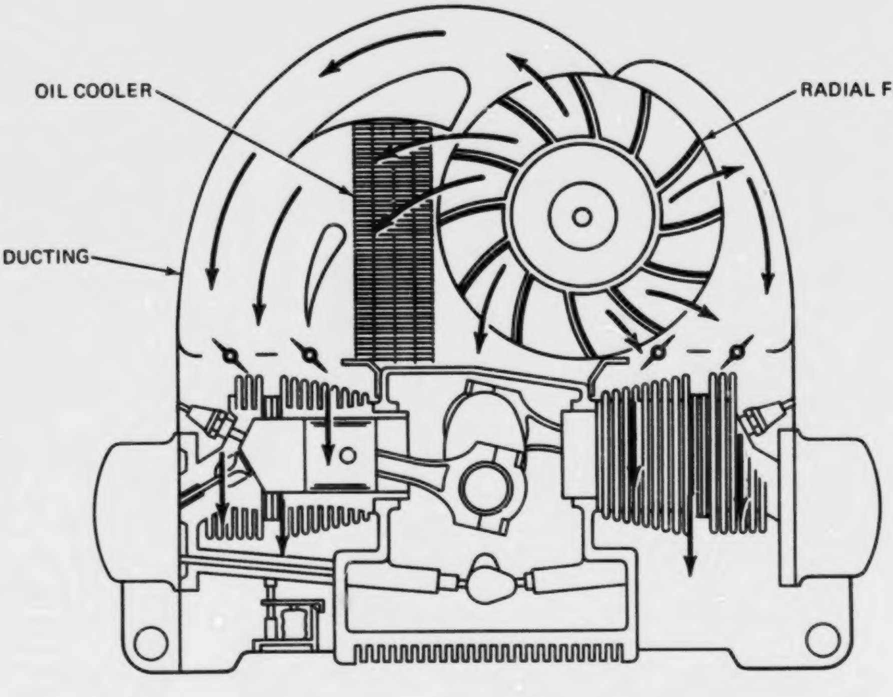

OIL COOLER
RADIAL FAN
DUCTING

Figure 8-11. Oil Cooler.

TA233488

200

BEST COPY AVAILABLE

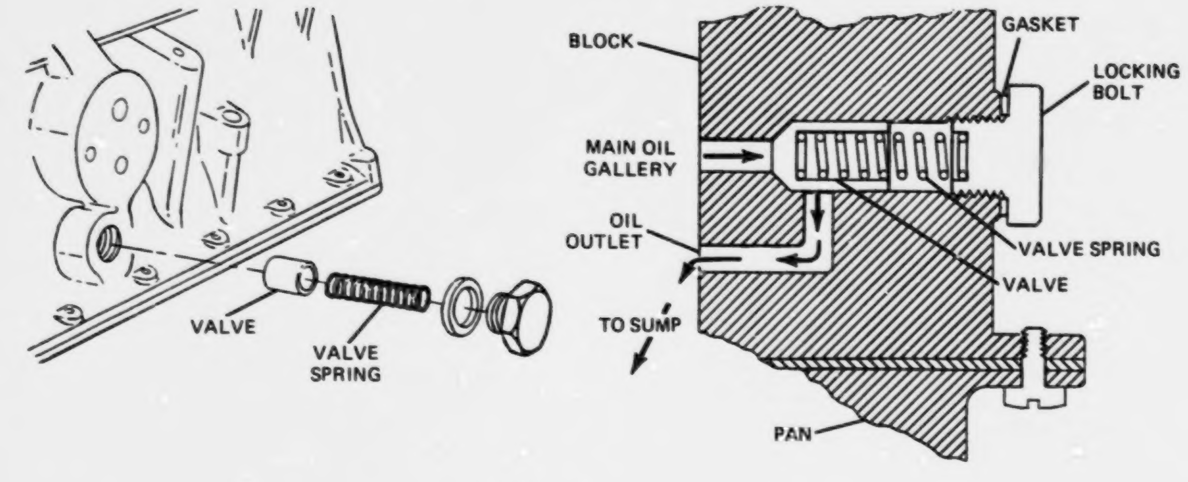


Figure 8-13. Oil Pressure Regulator.

Section IV. TYPES OF LUBRICATION SYSTEMS

8-17. Splash System (Fig. 8-14). The splash lubrication system no longer is used in automotive engines, though it is used in small equipment engines. In a splash lubrication system, dippers on the connecting rods enter the oil in the crankcase with each crankshaft revolution, thus splashing the oil. As the oil is thrown upward, it finds its way into the various engine parts. A passage is drilled in each connecting rod from the dipper to the bearing to ensure lubrication. This system is too uncertain for modern automotive applications. One reason is that the level of oil in the crankcase will vary greatly the amount of lubrication received by the engine; a high level results in excess lubrication and oil consumption and a slightly low level results in inadequate lubrication.

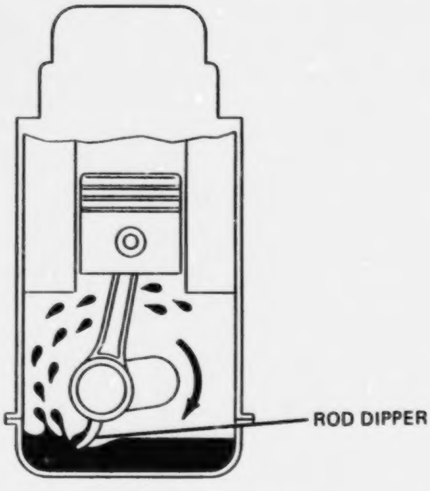


Figure 8-14. Splash-Type Lubrication System.

8-18. Combination Splash and Force-Feed System (Fig. 8-15). In the combination system, oil is delivered to some parts by means of splash and to other parts through oil passages, under pressure from a pump in the crankcase. The main and the camshaft bearings are usually the items that are force fed while the connecting rods are fitted with dippers that supply oil to the rest of the engine by splash. Some configurations utilize small troughs under each connecting rod that are kept full by small nozzles that deliver oil under pressure from the oil pump. These oil nozzles deliver an increasingly heavy stream as speed increases. At very high speeds these oil streams are powerful enough to strike the dippers directly. This causes a much heavier splash so that adequate lubrication of the pistons and the connecting rod bearings is provided at higher speeds. If a combination system is used on an overhead valve engine, the upper valve train is lubricated by pressure from the oil pump.

8-19. Force-Feed Lubrication System (Fig. 8-16). A somewhat more complete pressurization of lubrication is achieved in the force-feed lubrication system. Oil is forced by the oil pump

TA233489

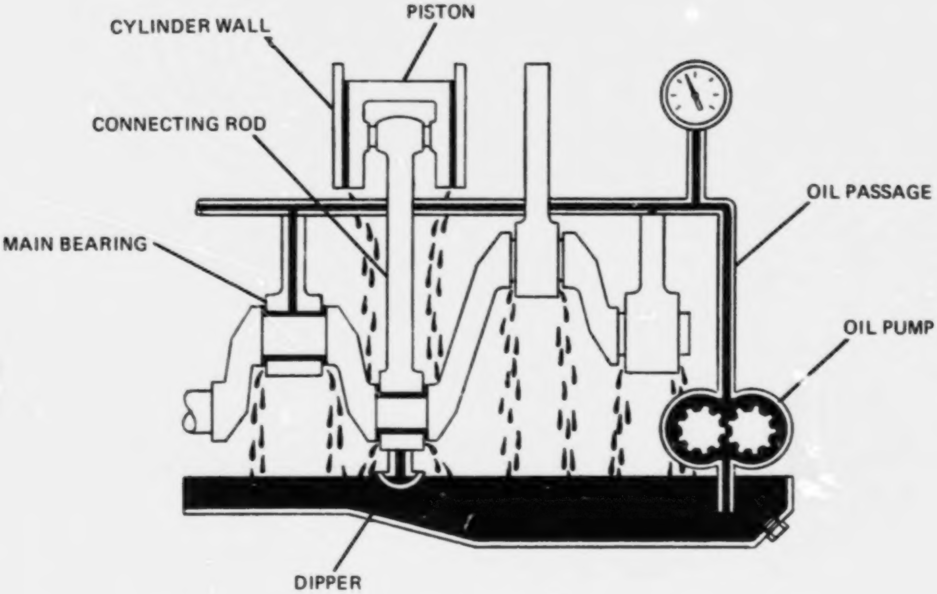

PISTON
CYLINDER WALL
CONNECTING ROD
OIL PASSAGE
MAIN BEARING
OIL PUMP
DIPPER

Figure 8-15. Combination Splash and Force-Feed Lubrication System.

from the crankcase to the main bearings and the camshaft bearings. Unlike the combination system (para 8-18) the connecting rod bearings are also fed oil under pressure from the pump. Oil passages are drilled in the crankshaft in order to lead oil to the connecting rod bearings. The passages deliver oil from the main bearing journals to the rod bearing journals. In some engines, these openings are holes that index (line up) once for every crankshaft revolution. In other engines, there are annular grooves in the main bearings through which oil can feed constantly into the hole in the crankshaft. The pressurized oil that lubricates the connecting rod bearings goes

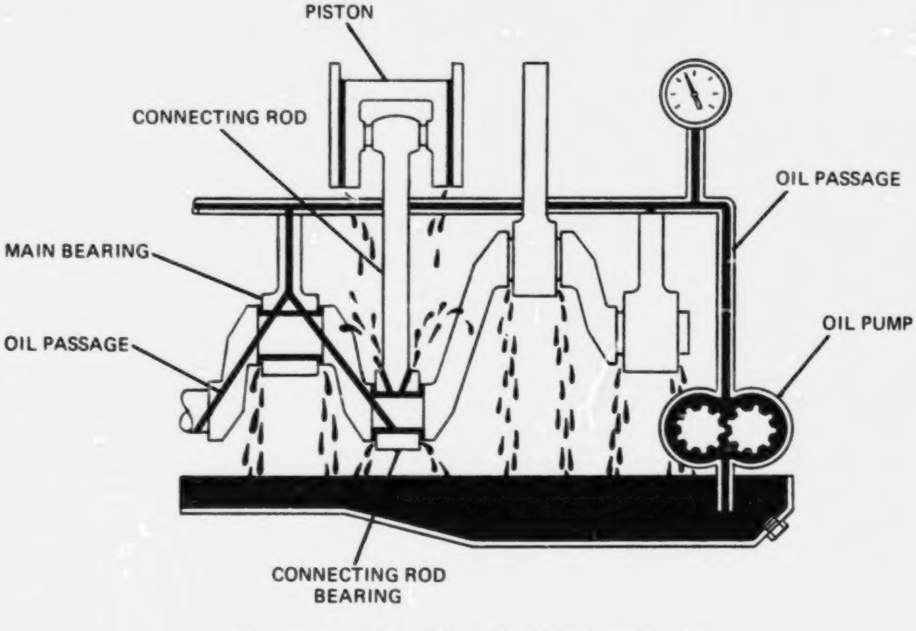

PISTON
CONNECTING ROD
OIL PASSAGE
MAIN BEARING
OIL PASSAGE
OIL PUMP
CONNECTING ROD BEARING

Figure 8-16. Force-Feed Lubrication System.

TA233490

202

on to lubricate the pistons and walls by squirting out through strategically drilled holes. This lubrication system is used in virtually all engines that are equipped with semifloating piston pins (para 3-7).

8-20. Full Force-Feed Lubrication System (Fig. 8-17). In the full force-feed lubrication system, all of the bearings mentioned in paragraph 8-18 are lubricated by oil under pressure. This includes main bearings, rod bearings, camshaft bearings, and the complete valve mechanism. In addition, the full force-feed lubrication system provides lubrication under pressure to the pistons and the piston pins. This is accomplished by holes drilled the length of the connecting rod, creating an oil passage from the connecting rod bearing to the piston pin bearing. This passage not only feeds the piston pin bearings, but also provides lubrication for the pistons and cylinder walls. This lubrication system is used in virtually all current automotive engines that are equipped with full-floating piston pins (para 3-7).

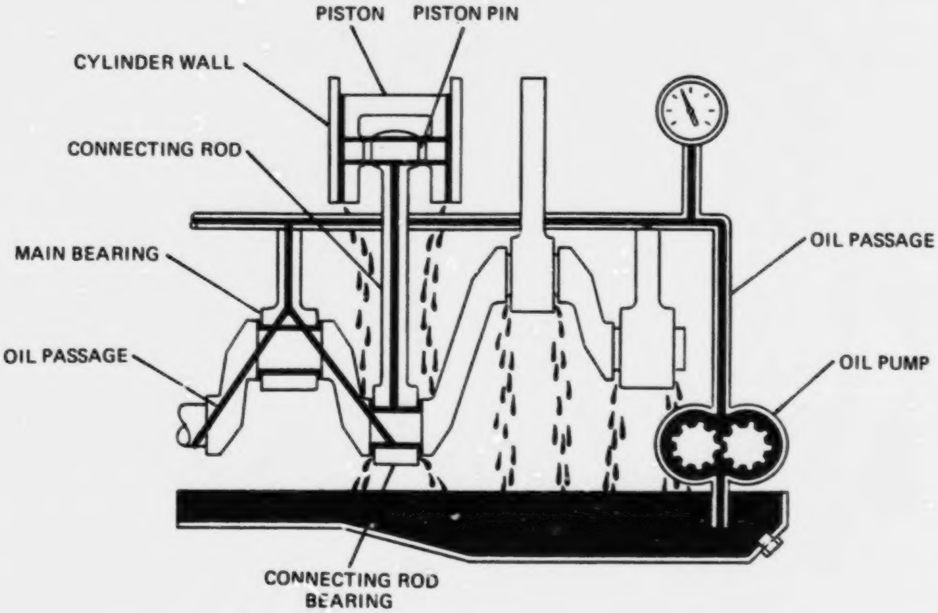


Figure 8-17. Full Force-Feed Lubrication System.

TA233491

CHAPTER 9

ENGINE COOLING SYSTEMS

Section I. COOLING ESSENTIALS

9-1. Need for Cooling. All internal combustion engines are equipped with some type of cooling system because of the high temperatures they generate during operation. High temperatures are necessary to generate the high gas pressures that act on the head of the piston. Power cannot be produced efficiently without high temperatures. However, it is not possible to use all of the heat of combustion without harmful results. The temperature in the combustion chamber during the burning of the fuel is well above the melting point of iron. Therefore, if nothing is done to cool the engine during operation, valves will burn and warp, lubricating oil will break down, and bearings and pistons will overheat, resulting in engine seizure.

9-2. Cooling Mediums.

a. Liquid. Liquid is the most popular coolant in automotive use. A liquid cooling system provides the most positive cooling and is best for maintaining an even engine temperature.

b. Air. Air cooling is most practical for small vehicles and equipment because no radiator or hoses are required. Air cooling generally will not be used wherever water cooling is practical. This is because air-cooled engines do not run at even temperatures and require extensive use of aluminum to dissipate heat.

c. Other Sources of Engine Cooling. There are other sources of heat dissipation for the engine in addition to the cooling system.

(1) The exhaust system dissipates as much, if not more, heat than the cooling system, although that is not its purpose.

(2) The engine oil, as stated in paragraph 8-1, removes heat from the engine and dissipates it to the air from the sump.

(3) The fuel provides some engine cooling through vaporization.

(4) A measurable amount of heat is dissipated to the air through radiation from the engine.

Section II. LIQUID COOLING SYSTEMS

9-3. Flow of Coolant (Fig. 9-1). A simple liquid-cooled cooling system consists of a radiator, coolant pump, piping, fan, thermostat, and a system of jackets and passages in the cylinder head and cylinder block through which the coolant circulates. Some engines are equipped with a water distribution tube inside the cooling passages that directs additional coolant to the points where the temperatures are highest. Cooling of the engine parts is accomplished by keeping the coolant circulating and in contact with the metal surfaces to be cooled. The pump draws the coolant from the bottom of the radiator, forces it through the jackets and passages, and ejects it into the upper tank on the top of the radiator. The coolant then passes through a set of tubes to the bottom of the radiator from which the cooling cycle begins again. The radiator is situated in front of a fan that is driven either by the water pump or an electric motor. The fan ensures an airflow through the radiator at times when there is no vehicle motion. It should be noted that the downward flow of coolant through the radiator creates what is known as a thermosiphon action. This simply means that as the coolant is heated in the jackets of the engine, it expands. As it expands, it becomes less dense and therefore lighter. This causes it to flow out of the top outlet of the engine and into the top tank of the radiator. As the coolant is cooled in the radiator, it again becomes more dense and heavier. This causes the coolant to settle to the bottom tank of the radiator. The heating in the engine and the cooling in the radiator therefore creates a natural circulation that aids the water pump. The earliest automotive vehicles relied on thermosiphon action and used no water pump.

9-4. Engine Water Jackets (Fig. 9-1).

a. The water passages in the cylinder block and cylinder head form the engine water jacket. In

204

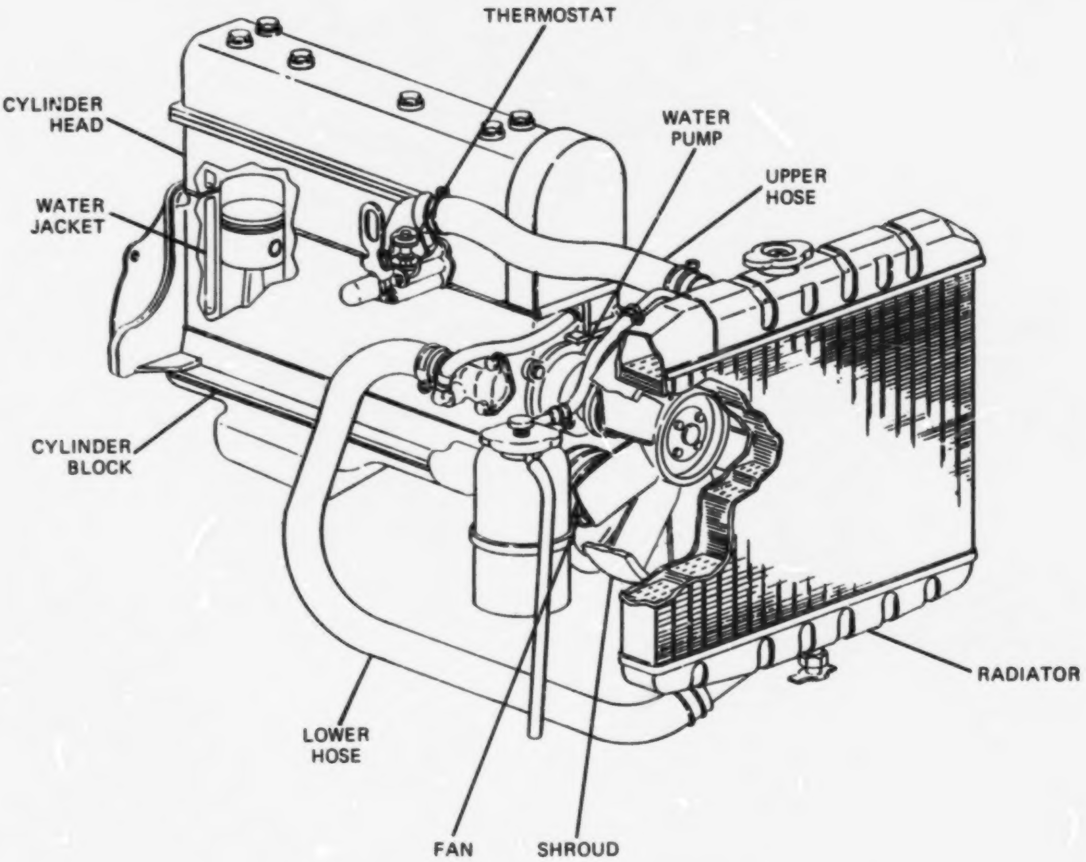


Figure 9-1. Liquid-Cooled System.

the majority of cylinder blocks the water jacket completely surrounds all cylinders along their full length. Within the jacket, narrow passages are provided between cylinders for coolant circulation. However, in some engine configurations the cylinder bores are attached to each other and a coolant passageway is not provided between bores. An engine of this design often is referred to as having siamese cylinders. This type of engine tends to operate with cylinder temperatures slightly higher between the bores, and cooler where water jackets come in contact with the bores. In addition, all engines are provided with water passages around the exhaust valve seat. This provides cooling for the valve when it comes in contact with the seat.

b. In the cylinder head, the water jacket covers the combustion chambers at the top of the cylinders and contains water passages around the valve seats when they are located in the head. The coolant flows from the cylinder block up into the cylinder head through passages called water transfer ports. A tight seal at the ports between the cylinder head and block is very important. The watertight seal at the ports, as well as the gastight seal at the combustion-chamber openings, is obtained with one large gasket called the cylinder-head gasket.

9-5. Coolants. Water is by far the most popular coolant for liquid-cooled engines. It is plentiful, inexpensive, and its boiling point is within the efficient operational temperature range of the engine.

a. Antifreeze Protection. When a vehicle is operated in areas where the temperature falls below 32°F (0°C), an antifreeze solution must be added if water is used as the coolant. The most common antifreeze is ethylene glycol. Other antifreezes that are little used are glycerin,

TA233492

205

BEST COPY AVAILABLE

methyl alcohol, and ethyl alcohol. Ethyl and methyl alcohol provide adequate protection as an antifreeze when used in sufficient quantities. The main objection to these liquids, however, is that they evaporate below the operating temperature of modern automotive engines, making them impractical. Glycerin offers the same degree of protection as alcohol, but does not evaporate in use because of its high boiling point. Ethylene glycol (antifreeze compound) has an extremely high boiling point, does not evaporate in use, is noncorrosive, has no odor, and gives complete protection against freezing in normal use. Ethylene glycol gives a maximum protection against freezing to – 65°F (– 53.8°C) when it is mixed to a solution of 60 percent with 40 percent water.

If the proportions of ethylene glycol are raised in the solution, it will result in a higher freezing point for the solution, consequently giving less protection. If a 100-percent solution of ethylene glycol were used, its freezing point would not be much below that of water. Other antifreeze solutions, however, do not show this increase of freezing point with increasing concentration. Two good examples are methyl alcohol, which freezes at -144°F (-97.8°C) and ethyl alcohol, which freezes at -174°F (-114.3°C).

b. Corrosion Resistance. The cooling system must be free of rust and scale in order to maintain its efficiency. The use of inhibitors or rust preventatives will reduce or prevent corrosion and the formation of scale. Inhibitors are not cleaners and therefore will not remove rust and scale that have already accumulated. Most commercially available antifreeze solutions contain inhibitors. If water alone is used as a coolant, an inhibitor should be added.

9-6. Radiators (Fig. 9-2). Radiators for automotive vehicles using liquid cooling systems consist of two tanks with a heat exchanging core between them. The upper tank contains an outside pipe called an inlet. The filler neck generally is placed on the top of the upper tank; attached to this filler neck is an outlet to the overflow pipe. The lower tank also contains an outside pipe that serves as the radiator's outlet. Operation of the radiator is as follows.

a. The upper tank collects incoming coolant

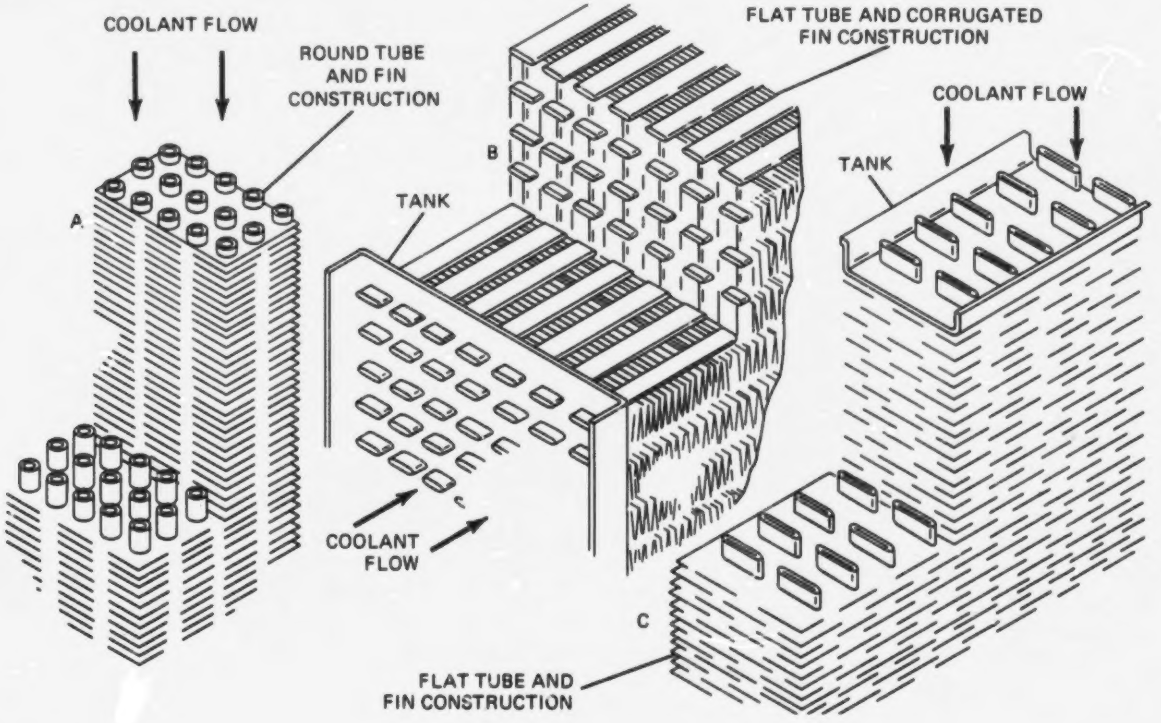

COOLANT FLOW
ROUND TUBE AND FIN CONSTRUCTION
A
B
FLAT TUBE AND CORRUGATED FIN CONSTRUCTION
TANK
COOLANT FLOW
TANK
COOLANT FLOW
C
FLAT TUBE AND FIN CONSTRUCTION

Figure 9-2. Engine Radiator Construction.

TA233493

and, through the use of an internal baffle, distributes it across the top of the core.

b. The core is made up of numerous rows of small vertical tubes that connect the upper and lower radiator tanks. Sandwiched between the rows of tubes are thin sheet metal fins. As the coolant passes through the tubes to the lower tank the fins conduct the heat away from it and dissipate this heat into the atmosphere. The dissipation of the heat from the fins is aided by directing a constant airflow between the tubes and over the fins.

c. The lower tank collects the coolant from the core and discharges it to the engine through the outlet pipe.

d. The overflow pipe provides an opening from the radiator for escape of coolant or steam if pressure in the system exceeds the regulated maximum. This will prevent rupture of cooling system components.

Some radiators are designed with their tanks on the sides in a vertical position. They are connected by a core that contains horizontal tubes. This radiator configuration is called a crossflow radiator and operates in the same manner as the conventional vertical flow radiator, though it should be noted that there is no thermosiphon effect (para 9-3) with a crossflow radiator.

9-7. Water Pump (Fig. 9-3). All modern cooling systems have water pumps to circulate the coolant. The pump, usually located on the front side of the engine block, receives coolant from the lower tank and forces it through the water jacket into the upper radiator tank. The pump is a centrifugal type and has an impeller with blades that force coolant outward as the impeller rotates. It usually is driven by the engine crankshaft through a V-belt. Advantages of a centrifugal pump as a water pump are that it is inexpensive, circulates great quantities of coolant for its size, and is not clogged by small amounts of foreign matter. Another advantage is that a centrifugal pump permits a limited amount of thermosiphon action after the engine is shut down to help prevent boilover. The pump housing usually is cast from iron or aluminum. The impeller can be made from iron, aluminum, or plastic. It rides on a shaft that is supported in the housing on a sealed double row ball bearing. The pump shaft also has a spring-loaded seal to prevent coolant leakage.

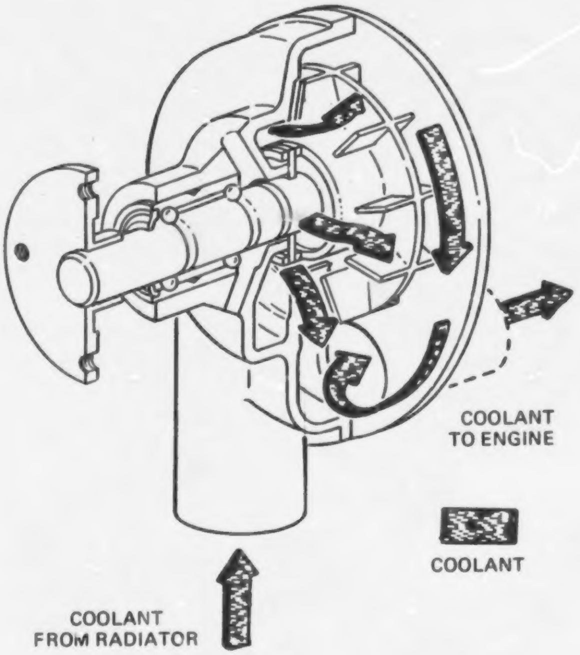


Figure 9-3. Water Pump Construction.

9-8. Fan and Shrouding (Fig. 9-1). The fan pulls a large volume of air through the radiator core so that engine heat can be dissipated effectively. In most cases the fan works in an enclosure called a shroud to ensure maximum efficiency of the fan. There are two methods of driving a fan. One method is to attach it to the end of the water pump shaft. The other method that is becoming increasingly popular is to utilize an electric motor.

a. Thermostatically Controlled Engine-Driven Fan. Some vehicles are equipped with a seven-blade fan, particularly those for heavy-duty use or those with air conditioning. This fan configuration will move tremendous amounts of air through the radiator to provide extra cooling capacity. The problem with a high-capacity fan is that it can cause the radiator core to freeze in cold weather. Other problems that are associated with a high output fan are excessive power consumption and noise at highway speeds. Most seven-blade fans are driven by the water pump through a viscous (fluid) clutch (fig. 9-4) to correct these conditions. The fan clutch is designed to limit the fan speed based on the

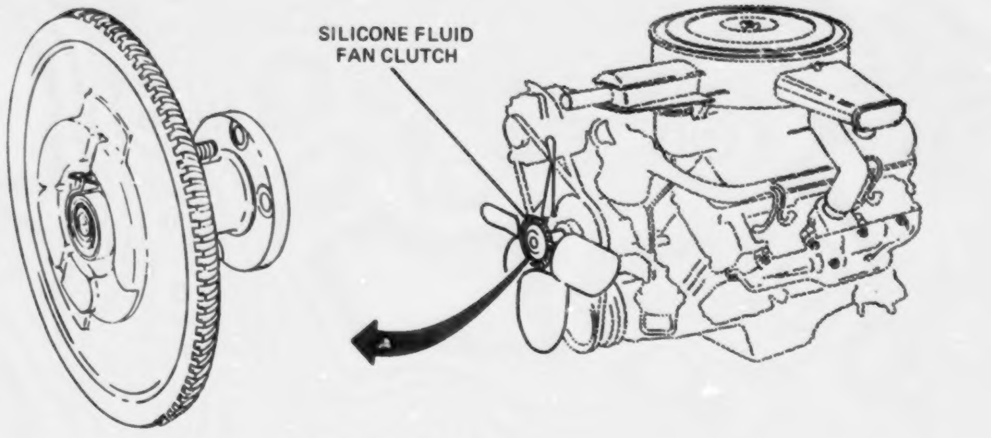


Figure 9-4. Viscous Fan Clutch.

temperature of the air drawn through the radiator. The clutch will provide controlled slippage if the temperature of this air is below a preset minimum. A fan clutch also will control the noise and the power consumption of the fan by limiting its speed to a preset maximum.

b. Electrically Motorized Fan (Fig. 9-5). The electrically motorized fan is gaining popularity in automotive use. In the newer configurations of front-wheel drive vehicles with transversely mounted engines, the electric fan is a necessity because the end of the engine is not located directly behind the radiator. Description and operation of the fan is as follows:

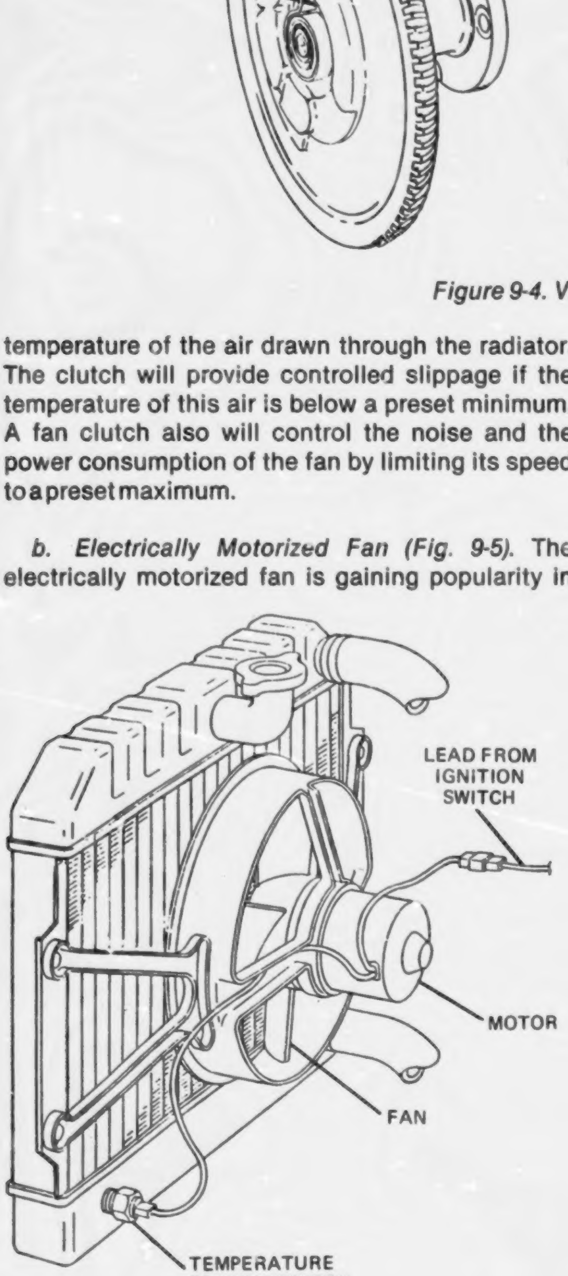


Figure 9-5. Electrically Motorized Fan.

(1) The fan blade is mounted on the motor shaft. The motor and fan blade assembly then is mounted directly behind the radiator core.

(2) The fan receives electric current through the ignition switch and a temperature sensitive switch located at the bottom of the radiator. The purpose of this radiator thermal switch is to turn on the fan to provide cooling whenever the temperature of the coolant reaches approximately 210°F (98.8°C). This serves to allow the fan to run only when needed.

(3) Some models incorporate a timed relay that allows the fan to run for a short time after engine shutdown. This, in conjunction with thermosiphon action (para 9-3) in the cooling system, helps to prevent boilover after engine shutdown.

c. Variable Pitch (Flexible) Fan Blades (Fig. 9-6). Some vehicles are equipped with blades that are made of flexible aluminum or fiberglass. These fan blades are made to change pitch as the speed of the fan increases so that the fan will not create excessive noise or draw excessive engine power at highway speeds.

TA233495

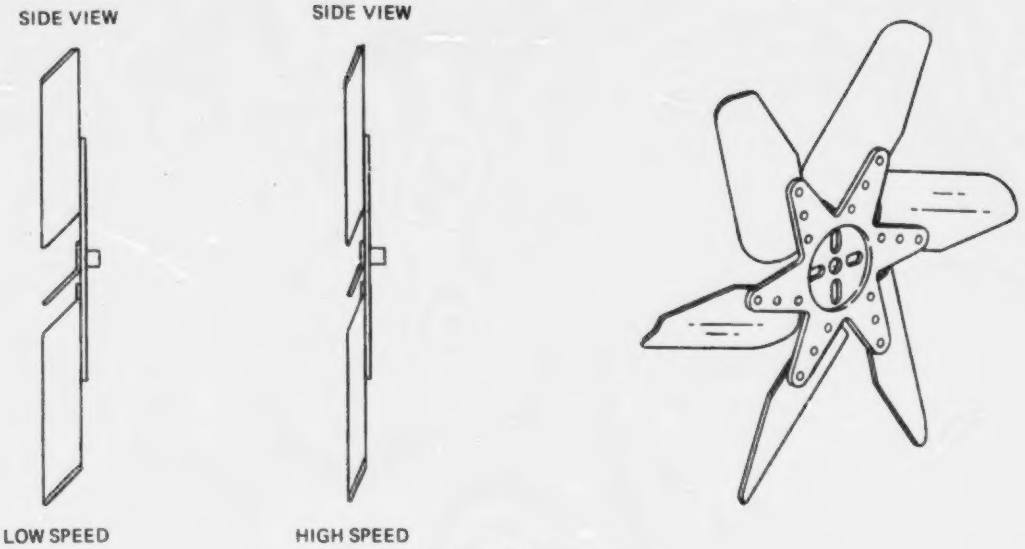


Figure 9-6. Variable Pitch Fan.

9-9. Thermostats.

a. Purpose. The water pump starts the coolant circulating through the system as soon as the engine is started, no matter how low the temperature. Therefore, it is necessary to install a thermostat to ensure quick warmup and prevent overcooling in cold weather. A thermostat regulates engine temperature by controlling automatically the amount of coolant flowing from the engine block to the radiator core.

b. Operation. The thermostat is merely a heat-operated unit that controls a valve between the engine block and the radiator. It usually is located in series with the engine coolant outlet in a casing called the thermostat housing. The thermostat, by design, is made so that if it fails, it will be in the opened position so as to allow the free circulation of coolant through the engine.

c. Configurations. The two configurations of the thermostat are:

(1) The bellows type (fig. 9-7), which consists of a flexible metal bellows attached to a valve. The bellows, which is sealed and expandable, is filled with a highly volatile liquid such as ether. The bellows chamber is contracted when the coolant is cold, holding the valve closed. The liquid in the bellows vaporizes as the coolant is heated, causing the bellows to expand. The bellows pull the valve open as they expand, allowing coolant to circulate. The bellows-type thermostat is little used in modern equipment because it is sensitive to the pressure around it, making it inaccurate in modern pressurized cooling systems.

(2) The pellet type (fig. 9-8), which is the currently used thermostat because its accuracy is unaffected by modern pressurized cooling systems. The thermostat consists of a valve that is operated by a piston or a steel pin that fits into a small case containing a copper impregnated wax pellet. When the engine is cold, the wax pellet is contracted and the spring pushes the valve closed. The wax pellet expands as the engine heats up, pushing the valve open against the force of the spring. The pellet-type thermostat will maintain a constant temperature by varying the size of the valve opening.

d. Thermostat Heat Ranges. A variety of thermostats are available that allow the coolant to operate at different temperatures. The standard heat ranges available are from 160°F (71°C) to 210°F (99.8°C).

e. Coolant Bypass (Fig. 9-9). The engine is designed so that the water pump will circulate coolant within the water jackets whenever the thermostat is closed. This is important to keep pistons and valves from overheating even though the engine is below operating temperature.

TA233496

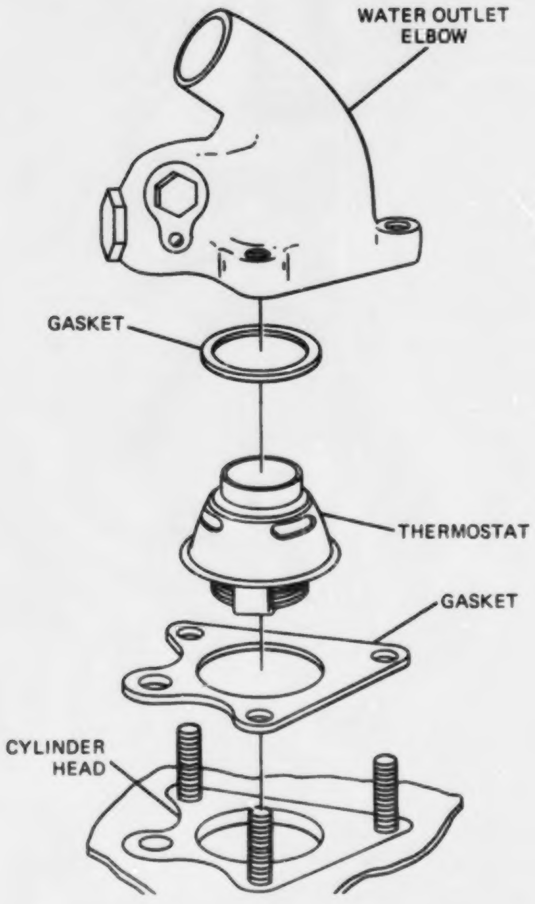


Figure 9-7. Bellows-Type Thermostat.

9-10. Radiator Pressure Cap.

a. Purpose. Modern automotive vehicles use pressurized cooling systems that allow a certain amount of pressure to develop within the system as its temperature goes up. The increase in pressure will raise the boiling point of the coolant proportionally, helping to prevent boilover.

b. Operation (Fig. 9-10). The cap contains two spring-loaded valves that are normally closed, sealing the system. The larger of these two valves is the pressure valve and the smaller is the vacuum valve. The pressure valve acts as a safety valve that will vent any pressure over the rated maximum through the overflow pipe. The vacuum valve allows air to enter the system as the engine cools down. This is to prevent atmospheric pressure from collapsing the hoses.

9-11. Expansion Tank (Fig. 9-11). Some vehicles use an expansion tank in their cooling systems. The expansion tank is mounted in series with the upper radiator hose. It is used to supply extra room for coolant expansion and generally takes the place of the upper radiator tank. The radiator pressure cap and the overflow line also are mounted on the expansion tank.

9-12. Closed Cooling System (Fig. 9-12).

a. Purpose. The purpose of a closed cooling system is twofold. First, the system is designed to maintain a completely full radiator at all times. This will increase the efficiency of the system by allowing a maximum amount of coolant in the system during all operating conditions. Second, during an overheating condition, the closed cooling system prevents coolant loss through the overflow line by collecting it in the recovery tank.

b. Operation. As the temperature of the cooling system rises, the pressure also will rise. This will open the pressure valve in the pressure cap, causing coolant to exit through the overflow tube, thus venting excess pressure. An open-type cooling system will empty coolant onto the road, causing a low coolant level after the temperature returns to normal. When a closed cooling system is used, the overflow line is connected to the bottom of a coolant recovery tank to catch and hold any expelled coolant. As the temperature of the coolant drops, the corresponding drop in pressure causes atmospheric pressure to push the coolant in the recovery tank back into the cooling system through the open vacuum valve in the pressure cap.

TA233497

210

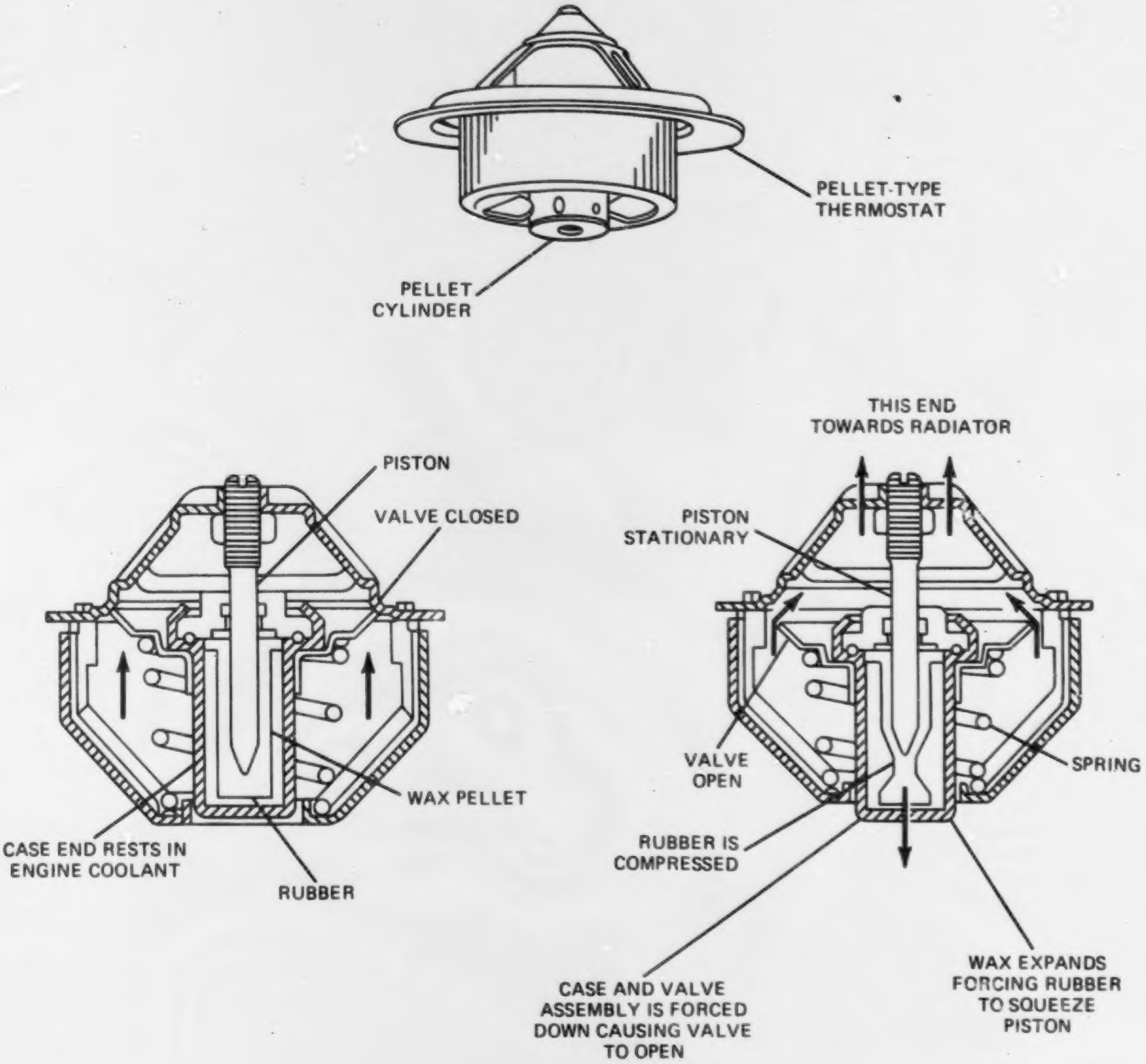
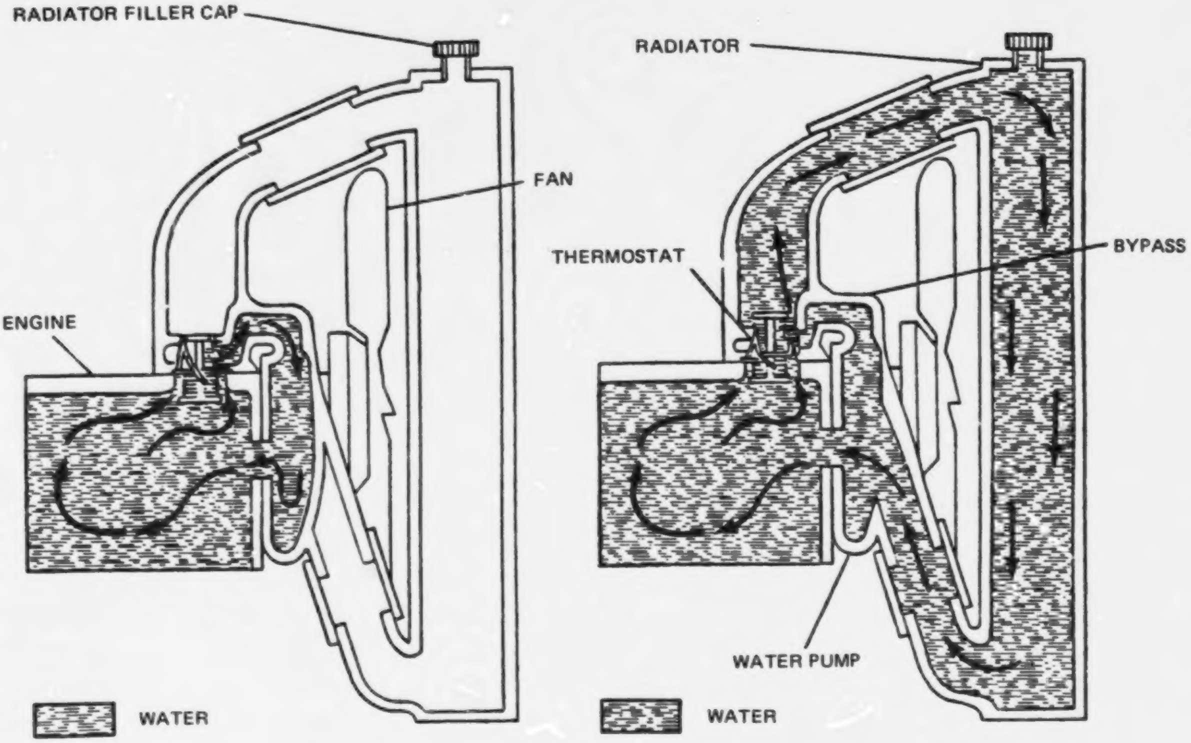

PELLET-TYPE THERMOSTAT
PELLET CYLINDER
PISTON
VALVE CLOSED
WAX PELLET
CASE END RESTS IN ENGINE COOLANT
RUBBER
THIS END TOWARDS RADIATOR
PISTON STATIONARY
SPRING
VALVE OPEN
RUBBER IS COMPRESSED
CASE AND VALVE ASSEMBLY IS FORCED DOWN CAUSING VALVE TO OPEN
WAX EXPANDS FORCING RUBBER TO SQUEEZE PISTON

Figure 9-8. Pellet-Type Thermostat.

TA233498


RADIATOR FILLER CAP
FAN
ENGINE
WATER
RADIATOR
THERMOSTAT
BYPASS
WATER PUMP
WATER

ENGINE COLD - VALVE CLOSED BY THERMOSTAT ALLOWS WATER TO CIRCULATE THROUGH THE ENGINE BUT NOT THE RADIATOR

ENGINE WARM - VALVE OPENED BY THERMOSTAT ALLOWS WATER TO CIRCULATE THROUGH THE ENGINE AND THE RADIATOR

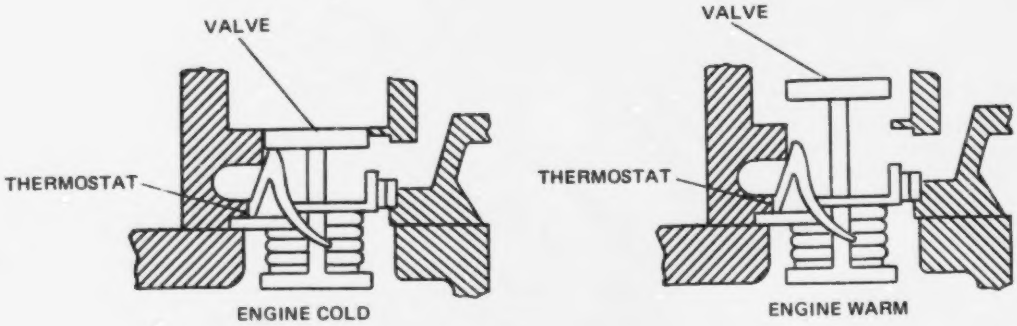

VALVE
THERMOSTAT
ENGINE COLD
VALVE
THERMOSTAT
ENGINE WARM

Figure 9-9. Coolant Bypass.

TA233499

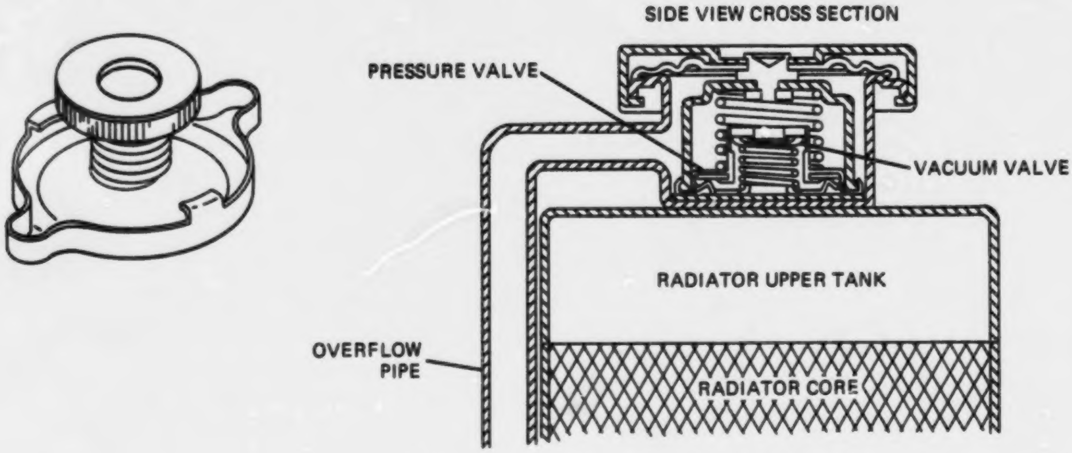

SIDE VIEW CROSS SECTION
PRESSURE VALVE
VACUUM VALVE
RADIATOR UPPER TANK
OVERFLOW PIPE
RADIATOR CORE

Figure 9-10. Pressure Cap.

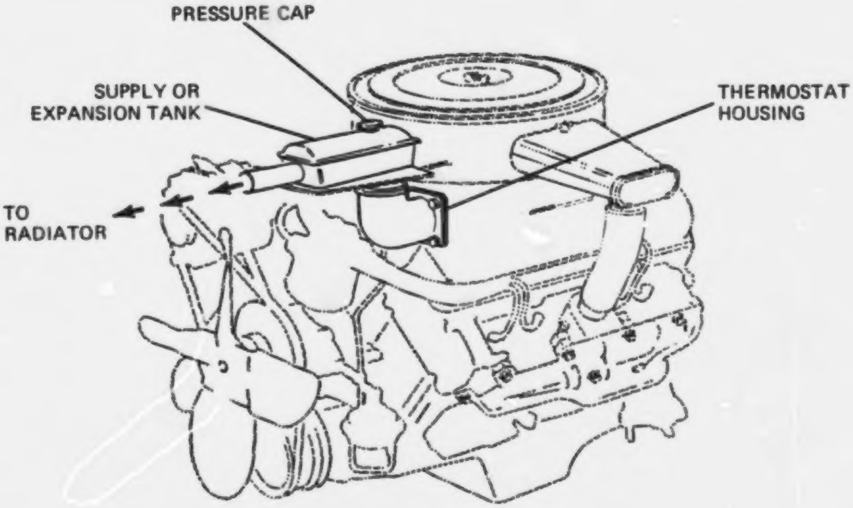
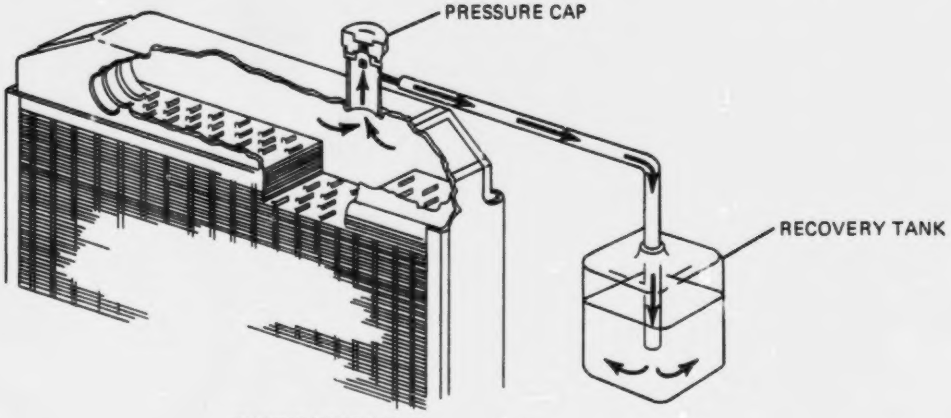

PRESSURE CAP
SUPPLY OR EXPANSION TANK
THERMOSTAT HOUSING
TO RADIATOR

Figure 9-11. Expansion Tank.

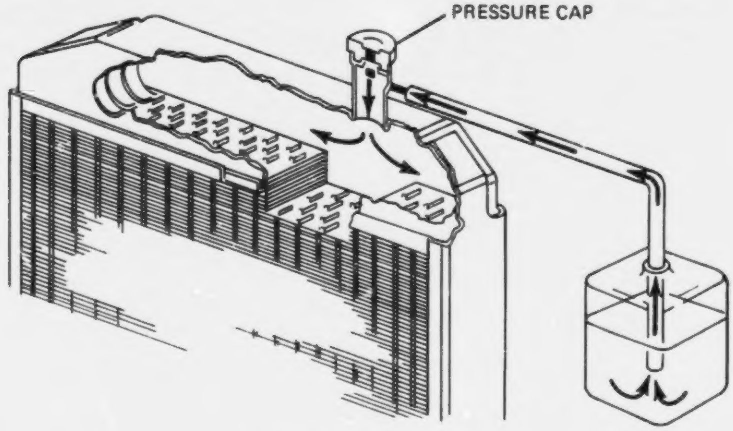
TA233500

213

BEST COPY AVAILABLE



ENGINE HEATING UP



ENGINE COOLS

Figure 9-12. Closed Cooling System.

Section III. AIR COOLING SYSTEMS

9-13. Principles (Fig. 9-13).

a. An air-cooled engine uses air as the principal cooling medium. Air-cooled engines are very easily identified by separate finned cylinders, finned cylinder heads, and in most cases, large cooling fans and extensive duct work.

b. The primary means of removing heat from an air-cooled engine is by dissipation to the air. The duct work and the cooling fans cause a constant flow of air over and around the cylinders and cylinder heads. The finned design of these components add a tremendous amount of surface area to them so that they are able to dissipate an adequate amount of heat.

c. An air cooling system, like a liquid cooling system, must be controlled to prevent overcooling of the engine. To accomplish this, a system of thermostatically controlled doors are usually incorporated into the ducting. The thermostat is usually a bellows that is filled with butyl alcohol. As the thermostat heats up, it opens the temperature control doors through linkage. When the doors are open, all of the cooling air is diverted through the engine cooling fins. When the doors are closed, all cooling air bypasses the engine and no cooling takes place. To maintain uniform engine

TA233501

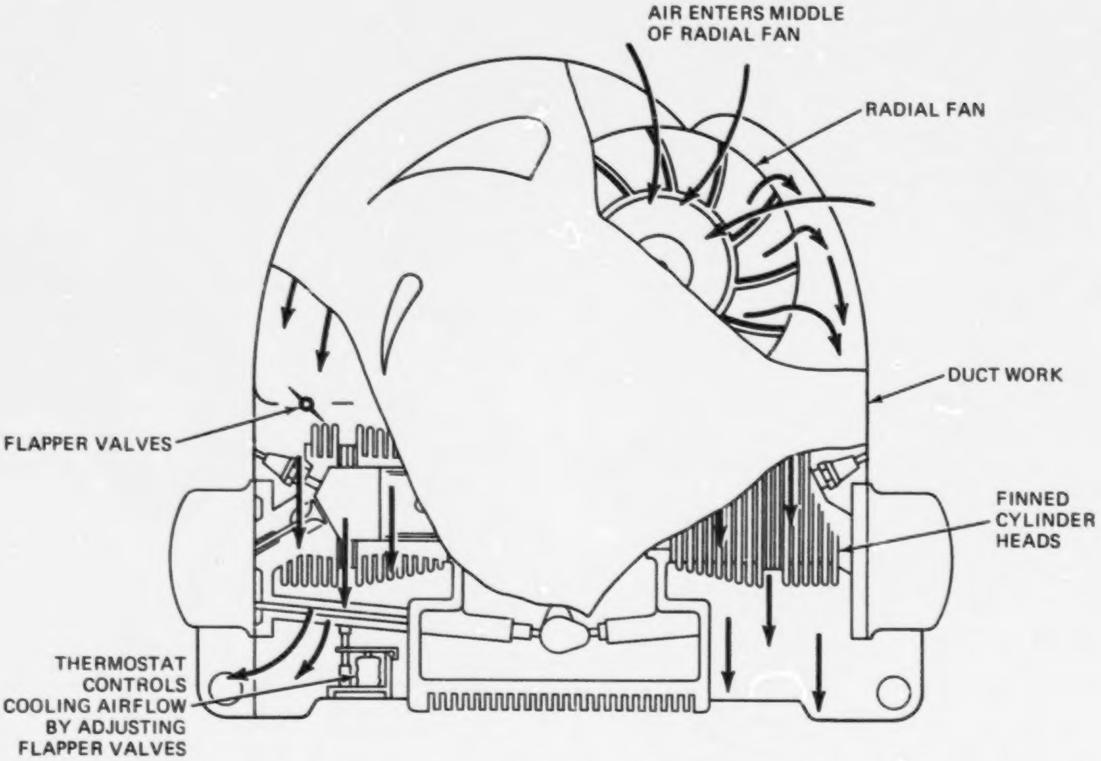

AIR ENTERS MIDDLE OF RADIAL FAN
RADIAL FAN
DUCT WORK
FLAPPER VALVES
FINNED CYLINDER HEADS
THERMOSTAT CONTROLS COOLING AIRFLOW BY ADJUSTING FLAPPER VALVES

Figure 9-13. Air Cooling System.

temperature, the thermostat, in most cases, will position the doors so that part of the cooling air bypasses and part of it cools. The thermostat, in the event of failure, is designed to open the doors fully to prevent overheating.

d. Because an air cooling system does not employ a liquid coolant, it often is assumed that air alone acts as the cooling medium. However, this is not true because, as was pointed out in paragraph 9-2, the fuel and the lubrication systems also help in cooling the engine. The lubrication system of an air-cooled engine always utilizes an air cooling system. There is also a certain amount of cooling as the fuel vaporizes in the intake manifolds and combustion chambers.

e. Virtually all air-cooled engines utilize an oil cooler to help in the cooling process. The oil cooler unit usually is located in the ducting so that it is exposed to the forced air from the cooling fan. Its operation is the same as that described in paragraph 8-14.

TA233502

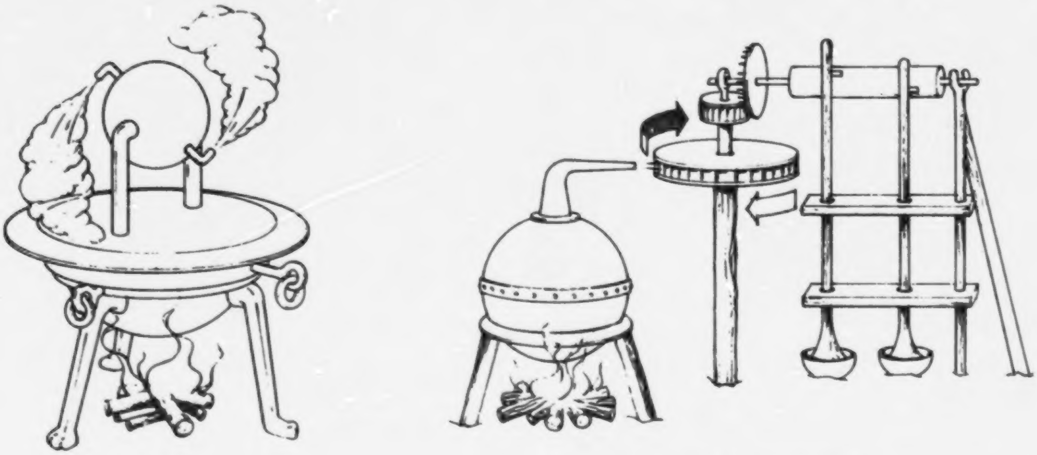
CHAPTER 10

GAS TURBINE ENGINES

Section I. OVERVIEW

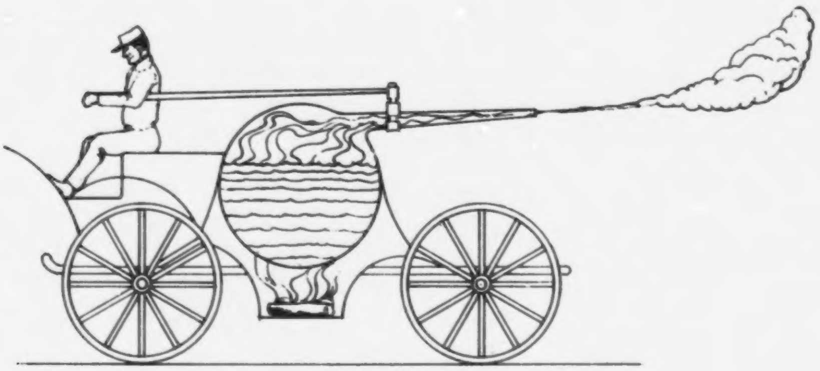
10-1. History of the Turbine Engine. There are two types of engines that provide most of our power today: the gas turbine (the older of the two) and the piston engine. The basic idea of the gas turbine is over 2,000 years old. The principle of the gas turbine was used to obtain continuous turning of the spit for roasting meat over an open fire. Turbine blades were placed in the chimney to be turned by the rising hot gases. The blade-carrying shaft was connected through gearing to the spit to obtain a very slow rotary motion. Modern science and engineering has made possible the advent and use of this principle. For centuries man has devoted himself to the task of harnessing energy for the betterment of mankind. Ever since man's first use of fire in the early ages, it has been his desire to put energy to work in more efficient ways and means. The following three examples are early applications of turbine engines.

a. Aeolipile (Fig. 10-1). The first reaction engine known to be used to perform work was built in approximately 150 BC by Hero of Alexandria,



AEOLIPILE

BRANCA'S STAMPING MILL



NEWTON'S STEAM WAGON

Figure 10-1. Early Examples of Gas Turbine Engines.

TA233503

and was called an aeolipile. It consisted essentially of a boiler, suspended over a fire, from which two tubes led to a closed vessel in the shape of a sphere, into which steam under pressure was introduced. When the steam escaped from two bent tubes mounted opposite one another on the surface of the sphere, the tubes became jet nozzles. A force was created at the nozzles that caused the sphere to rotate around an axis.

b. Branca's Stamping Mill (Fig. 10-1). A further application of the gas turbine propulsion principle, utilizing what was probably the first actual impulse turbine, was the invention of a stamping mill built in 1629 by Giovanni Branca, an Italian engineer. The turbine was driven by steam generated in a boiler. The jet of steam from a nozzle in this boiler impinged on the blades of a horizontally mounted turbine wheel which, through an arrangement of gearing, caused the mill to operate.

c. Newton's Steam Wagon (Fig. 10-1). In 1687, Sir Isaac Newton formulated the laws of motion and employed the basic principle used by Hero. The wagon consisted essentially of a large boiler mounted on four wheels. Steam generated by a fire built below the boiler was allowed to escape through a nozzle facing rearward. The speed of the vehicle was controlled by a steam cock located in the nozzle. The steam wagon demonstrates Newton's Third Law of Motion: For every action, there is always an equal and opposite reaction.

10-2. Introduction. Gas turbines are internal combustion engines. They generate power by compressing a gas (air) that has been pumped into a suitable chamber, adding heat energy (by burning fuel), and expanding and expelling the heated gas through a nozzle using rotating machinery that carries out the process in a steady flow. The gas that operates the turbine is the product of the combustion that takes place when a suitable fuel is mixed and burned with the air passing through the engine. The gas turbine represents one of man's more ingenious means of harnessing energy. With the use of a few pounds of heat-resistant metal, properly shaped, and in the presence of pressurized combustion gases, well supplied with heat, the gas turbine is capable of harnessing probably more mechanical shaft energy than any other manmade device of equal size and weight.

10-3. Theory of Operation. In order to master the theory of operation behind the gas turbine engine, four basic principles must be understood: mass, pressure, accelerated mass, and conversion of energy. Each is discussed below.

a. Mass. All turboshaft engines attain their high rotational torque output, or power, from energy transferred to the turbines by the accelerated airmass within the engine. Figure 10-2 illustrates this concept. Within container 1 there are a certain amount of air molecules; the exact amount is referred to as mass. This airmass is one of the key components required to drive the turbine in the mass acceleration principle.

b. Pressure. A second component required in the acceleration principle is pressure, or driving force. To attain this pressure, container 2 (fig. 10-2) is heated and the molecules contained within expand and exert pressure equally in all directions.

c. Accelerated Mass. An accelerated mass is obtained by funneling the pressurized gas down a narrow passageway (container 3). It is this convergency or narrowing down of the nozzle area that causes the molecules to accelerate and produce the velocity energy required to perform the rotational mechanical work.

d. Conversion of Energy. The high-velocity gases possess a large amount of kinetic energy. This energy due to motion now must be converted to mechanical energy, which can be accomplished by adding a turbine wheel to container 4 (fig. 10-2). The first force, as seen in the illustration, is the impact or push of the high-velocity gases exiting the nozzle and hitting the turbine wheel. The second force, which is a reaction force, is generated by the high-velocity gases exiting the turbine wheel in the opposite direction of rotation.

217

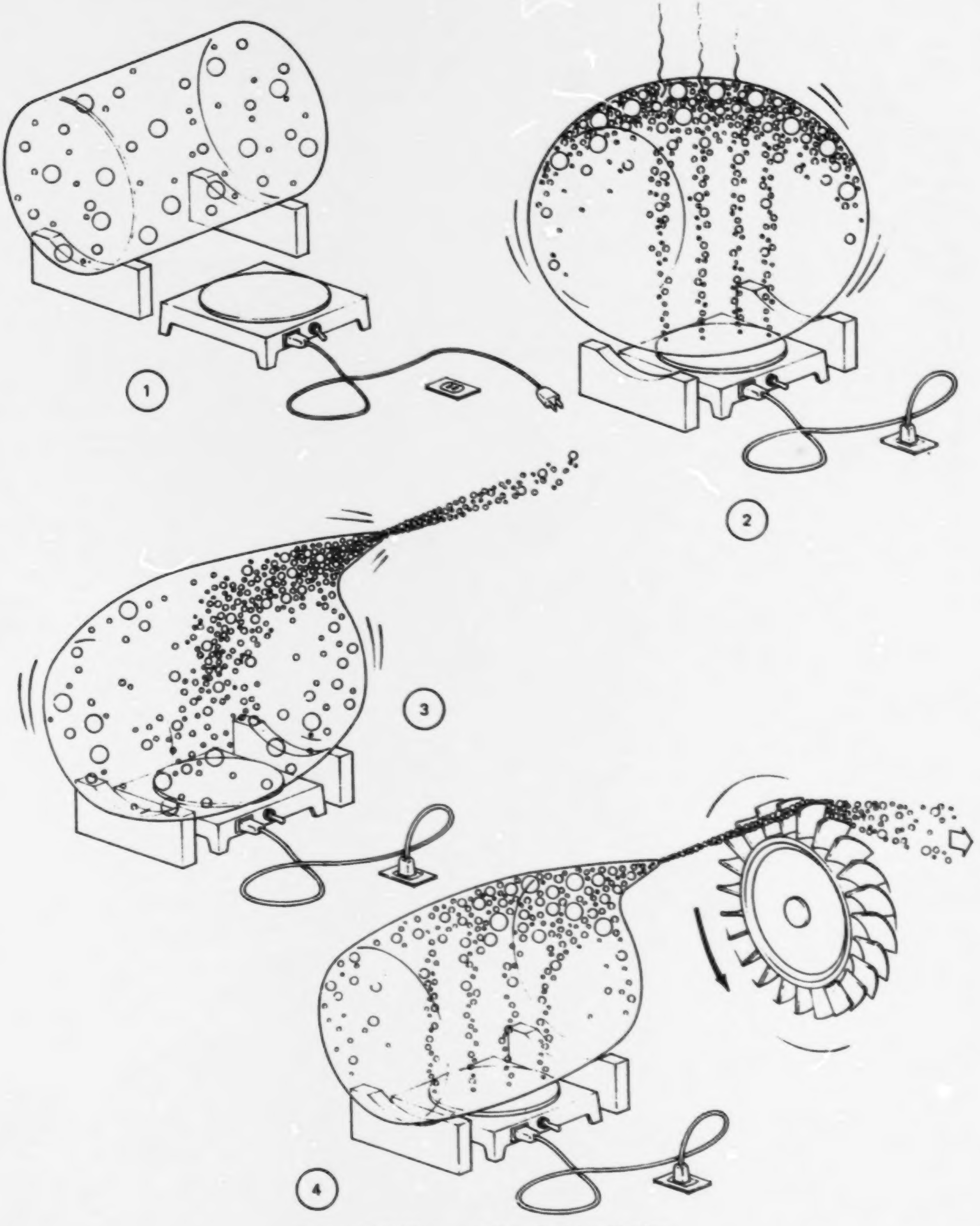


Figure 10-2. Theory of Gas Turbine Engine.

TA233504

218

Section II. COMPARISON TO PISTON ENGINE

10-4. Cycle Characteristics and Variations. The four-stroke/cycle piston-type engine is designed to perform four events: intake, compression, power, and exhaust. One cycle (four events) is completed as the crankshaft rotates twice for a total of 720 degrees (fig. 10-3). Each event is completed within 180 degrees of crankshaft rotation and is called a stroke. Gas turbine engine operation consists of four events that are essentially the same as the reciprocating engine. Air is first drawn through the air inlet section that relates to the intake event. It then passes through the compressor section, relating to the compression event. The air then enters the combustor, mixes with fuel, and is ignited. As the air-fuel mixture burns, the pressure increase is directed through the turbines that extract work from the flowing gases which relates to the power event. Passing through the turbines, the used gases are exhausted to the atmosphere, relating to the exhaust event. Figure 10-3 illustrates the comparison of events between the four-stroke/cycle piston-type engine and the gas turbine.

10-5. Otto Cycle Versus Brayton Cycle.

a. Otto Cycle. Both the piston engine and the gas turbine operate on cycles that can be represented graphically. Figure 10-4 illustrates the pressure/volume relationship for both the Otto-cycle engine and the Brayton-cycle engine. The Otto-cycle engine pressure/ volume relationship is as follows: The intake stroke is represented by line 1-2. As this event occurs, the piston is moving downward, increasing the volume in the cylinder. At the close of the intake valve, a slight pressure differential occurs, due to pumping losses. This results in a small vacuum in the cylinder at the start of the compression stroke. Line 2-3 illustrates the compression

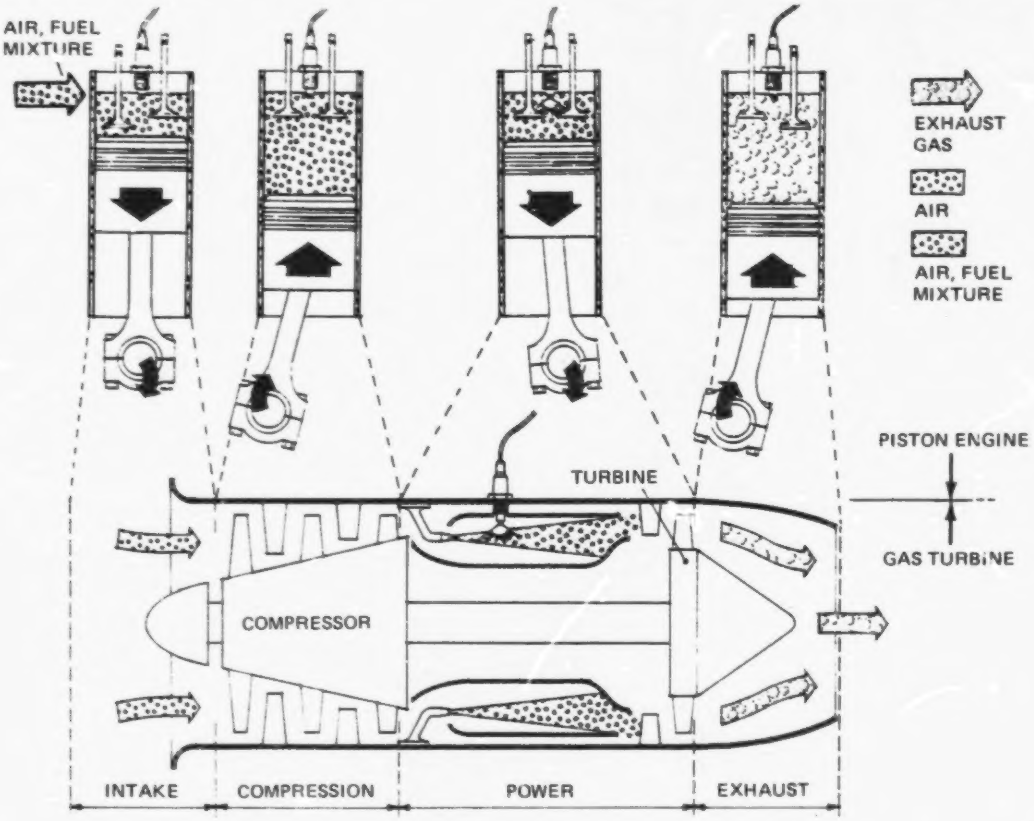


Figure 10-3. Comparison of Piston Engine to Turbine Engine.

TA233505

249

BEST COPY AVAILABLE

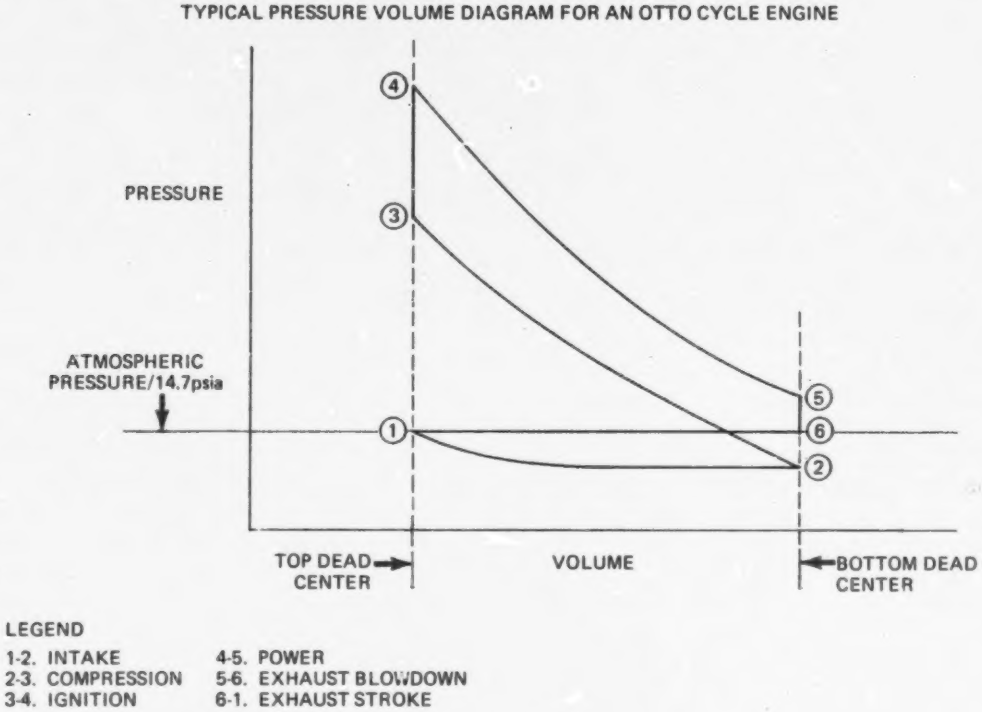


Figure 10-4. The Otto Cycle.

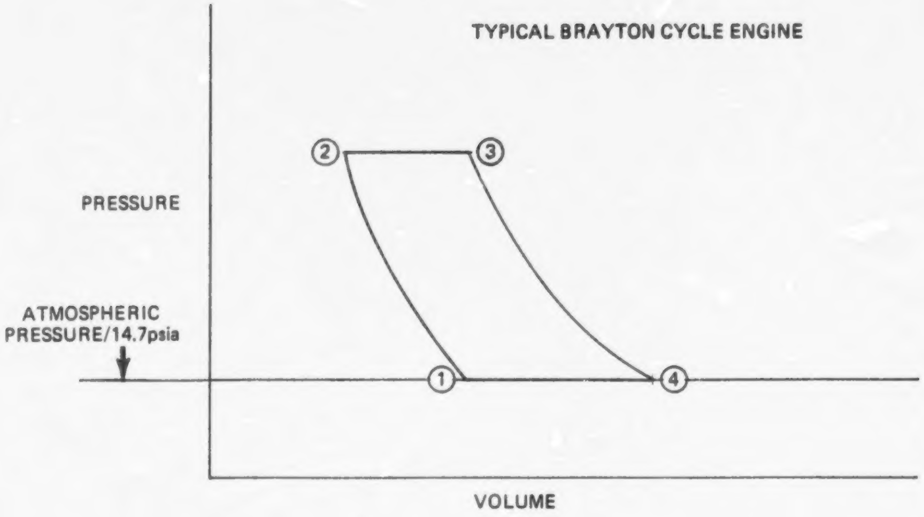
sequence. As the piston travels upward, the volume in the cylinder decreases, resulting in a pressure rise. At line 3-4 ignition occurs. Igniting the charge at a constant volume causes a severe pressure increase in the cylinder. The piston now begins to move downward on the power stroke (line 4-5). As this happens, the pressure in the cylinder decreases as the moving piston increases the volume. At point 5 the exhaust valve opens and the cylinder is allowed to blow down. As this happens near the end of the power stroke, the volume remains constant and pressure rapidly decreases. Line 6-1 indicates the action that happens during the exhaust stroke. The piston moves upward to expel the burned gases causing a decrease in volume. As a result of the cylinder being vented to the atmosphere, the pressure remains close to atmospheric in the cylinder during this stroke.

b. Brayton Cycle. Figure 10-5 graphically illustrates the pressure/volume relationship for the Brayton-cycle engine. At point 1 air enters the compressor at constant pressure (atmospheric) and constant volume. Line 1-2 illustrates an increase in pressure and decrease in volume, relative to the compression process. Combustion takes place by maintaining constant pressure and increasing volume due to the heated charge being ignited (line 2-3). As power is extracted by the turbine blades, the pressure is decreased and volume increases (line 3-4). The combustion charge then is exhausted (line 4-1), causing a drop in volume to point 1 on the graph.

10-6. Continuous Combustion. As discussed above, the four-stroke/cycle piston-type engine performs four separate discrete events. Each event must be completed before the next one begins. Basic gas turbine engine operation consists of four events that are essentially the same as the piston-type reciprocating engine; however, these events combine to form a continuous cycle. As the gas turbine operates, each of the four events transpires continuously. In the gas turbine engine, as long as there is a supply of air and fuel to burn, expand, and maintain turbine speed, the cycle is said to be continuous and self-sufficient.

10-7. Thermal Comparison. The piston-type engine operates at relatively cooler temperatures

TA233506



LEGEND
1. AIR ENTERS AT ATMOSPHERIC PRESSURE
1-2. COMPRESSOR SECTION DECREASES VOLUME AND INCREASES PRESSURE
2-3. COMBUSTION AT POINT 2 RESULTS IN MAINTAINING CONSTANT PRESSURE WITH AN INCREASE IN VOLUME
3-4. GAS ENTERS TURBINE AREA WHICH CAUSES A DECREASE IN PRESSURE AND AN INCREASE IN VOLUME
4-1. COMBUSTION CHANGE IS RELEASED

Figure 10-5. The Brayton Cycle.

than the gas turbine engine. The piston engine withstands combustion chamber temperatures of approximately 5000°F (2760°C) for a short duration of time. The hot components are cooled rapidly to maintain relatively low temperatures of only a few hundred degrees. In the gas turbine, the combustion chamber maintains a constant temperature and limits it to approximately 1000° to 2000°F (537.7° to 1093.3°C). This is done to retain the resilience of internal components and inhibit formation of foreign matter on rotating parts.

Section III. BASIC ENGINE STRUCTURE

10-8. Air Inlet Section. The air inlet section (fig. 10-6) serves to furnish a uniform and steady airflow to the face of the compressor. Inlet sections may be equipped with or without inlet guide vanes. Inlet guide vanes serve to direct the air into the first stage of the compressor.

10-9. Compressors. The compressor is designed to provide the combustion chamber with a maximum amount of high-pressure air that is heated and expanded through the turbines. The amount of energy released from the heated airmass is proportional directly to the mass of air consumed. This is the major reason why the compressor is one of the most important components in the gas turbine. A poorly designed compressor will not provide the combustion chamber with the proper amount of high-pressure air, and will result in a lack of power. Modern compressors are able to achieve compression ratios of approximately 15:1 and efficiencies approaching 90 percent. Two common types of compressors are discussed below.

a. Axial. The axial compressor performs the compression process in a straight line parallel to the axis of the engine. The axial compressor is composed of rotating members called rotors and stationary members called stators. A row of rotors and stators is called a stage. The axial compressor is composed of a series of stages (fig. 10-7). During operation the air is arrested in the first stage of compression and is turned by a set of stator vanes, picked up by a set of rotor blades,

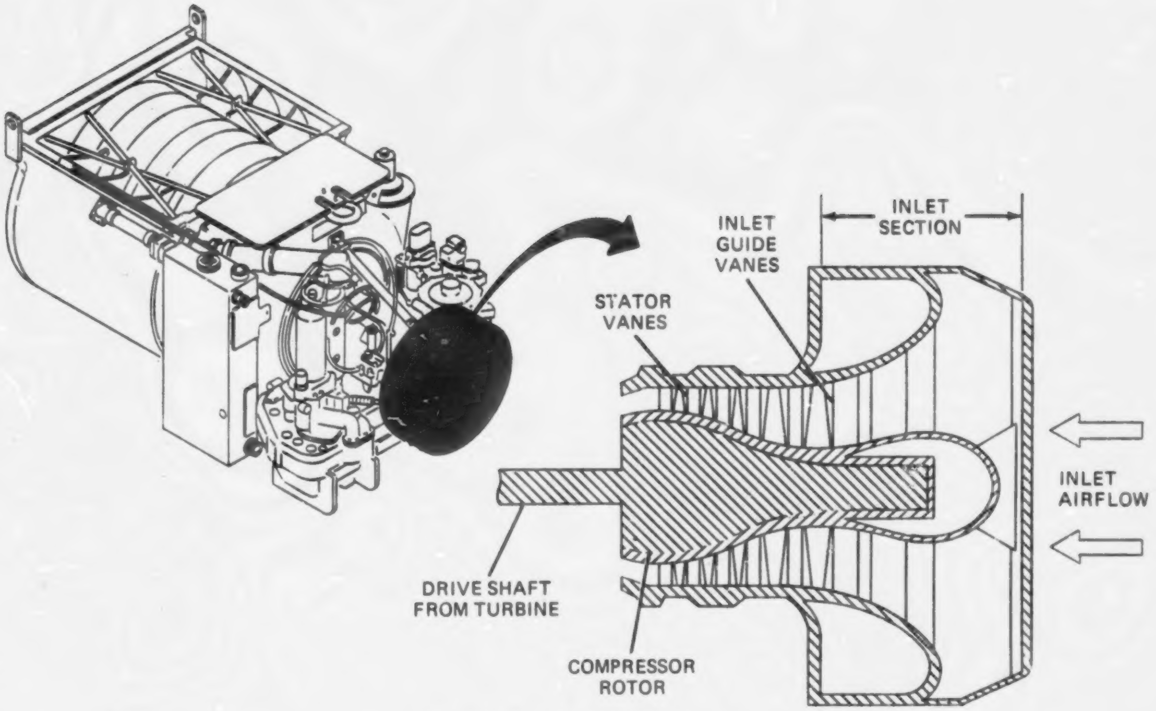


Figure 10-6. Air inlet Section.

and passed through each successive stage to complete compression. The rotors increase velocity while the stators decrease the velocity. The successive increases and decreases in velocity practically cancel each other, with a result that the velocity, as the air leaves the compressor, is usually slightly greater than the velocity of the air at the entrance to the compressor. As the pressure is built up by successive sets of rotors and stators, less and less volume is required. Thus, the volume within the compressor is decreased gradually. At the exit of the compressor, a diffuser section within the engine adds the final touch to the compression process by decreasing again the velocity and increasing the static pressure just before the air enters the engine burner section.

b. Centrifugal Compressors. This type of compressor consists of two main parts: an impeller and a diffuser. Centrifugal compressors operate by taking in air near the hub of the impeller and accelerating it outward by centrifugal action. The impeller vanes guide the air toward the outer circumference of the compressor, building up the velocity by means of the high rotational speed of the impeller. Air leaves the impeller at high speed and flows through a set of diffuser vanes which decelerates the flow of air, converting high-velocity air to high-pressure energy. The diffuser vanes also serve to straighten airflow. A typical centrifugal compressor is shown in figure 10-8. Centrifugal compressors achieve efficiency ratings of 78 to 84 percent and compression ratios of approximately 5:1.

10-10. Combustion Chamber. The combustion chamber (fig. 10-9) is designed to burn a mixture of fuel and air, and to deliver the resulting gases to the turbine at a temperature that will not exceed the allowable limits at the turbine inlet. The chamber, within a very limited space, must add sufficient heat energy to the gases passing through the engine. This accelerates their mass enough to produce the desired power for the turbine section. Combustion chambers are built in a number of different designs. The construction is such that less than one-third of the total volume of air entering the chamber is permitted to mix with the fuel. The remaining air is used downstream to cool the combustor surfaces, and to mix with and cool the burned gases before they enter the turbines.

TA233508

222

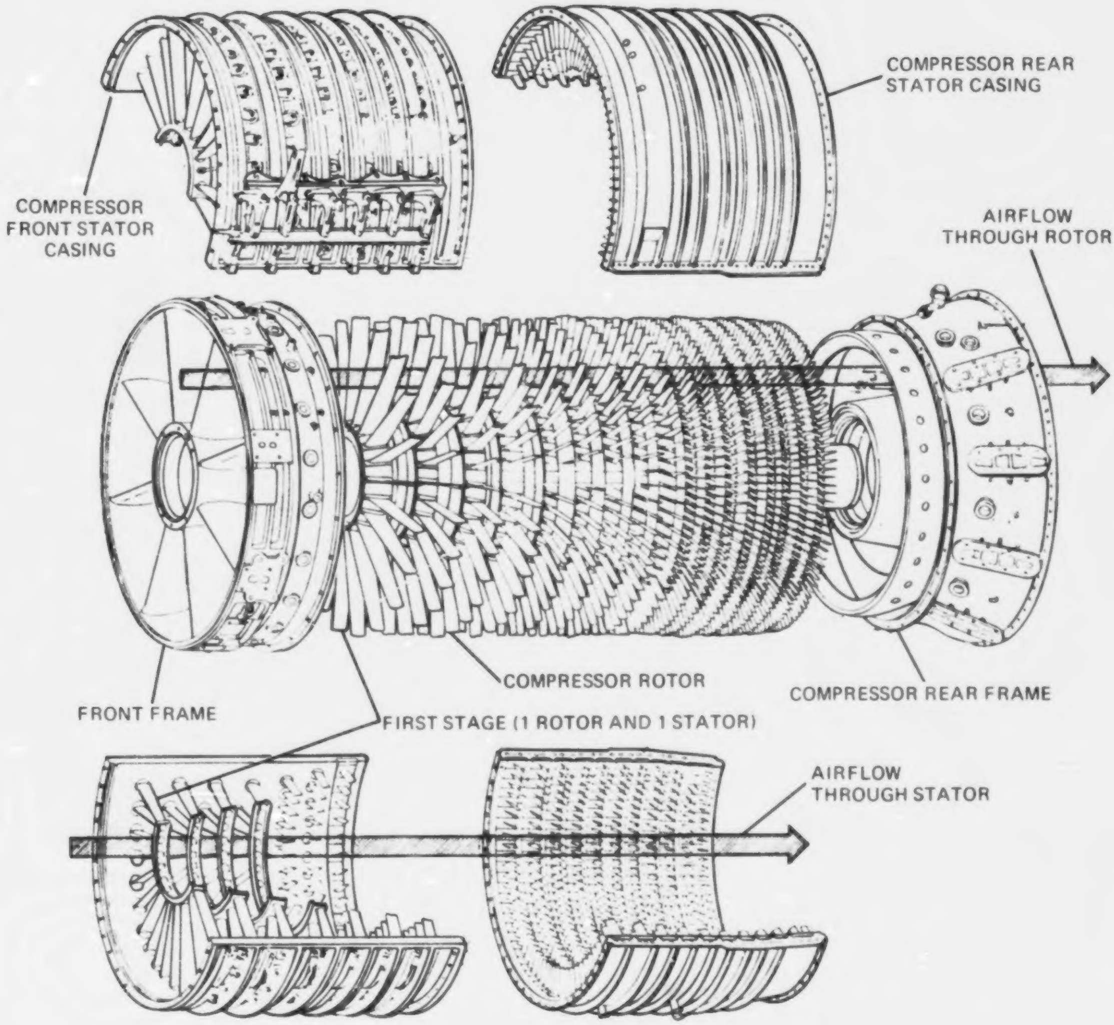

COMPRESSOR REAR STATOR CASING
COMPRESSOR FRONT STATOR CASING
AIRFLOW THROUGH ROTOR
COMPRESSOR ROTOR
COMPRESSOR REAR FRAME
FRONT FRAME
FIRST STAGE (1 ROTOR AND 1 STATOR)
AIRFLOW THROUGH STATOR

Figure 10-7. Axial Compressor.

10-11. Recouperator. The function of the recouperator, also called regenerator, is to transfer heat from the exhaust gases to the air entering the engine. This process allows the incoming air to expand prior to combustion. As a result, less heat is required during the combustion process to obtain a fully expanded airmass with maximum velocity. The recouperator is cylindrically shaped with a hollow passageway through the middle. Triangular- and oval-shaped ports are placed alternately around the perimeter and pass through the length of the recouperator (fig. 10-10). Two different types of plates are alternately stacked to construct the recouperator. The air plate (A, fig. 10-11) is constructed with a flat pathway between the oval and triangular ports. The incoming cool air passes down the triangular ports and enters a passage between triangular and oval ports. As the air passes through the pathways, it is heated by exhaust gases exiting above and below the pathway. The exhaust gas enters the middle of the recouperator, passes through heater plates (B, fig. 10-11), and exits the outside of the unit, giving up heat to the cool air in the process. The benefits obtained from the use of a recouperator are listed below.

a. High thermal efficiency.

TA233509

223

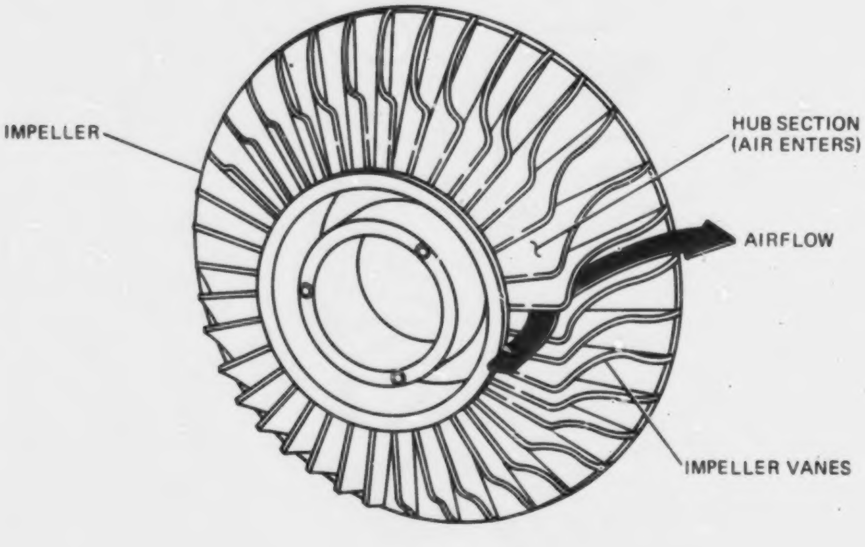


Figure 10-8. Centrifugal Compressor.

b. Low specific fuel consumption.

c. Lowered exhaust temperature.

Basically, the only disadvantage to this system is the additional weight of the unit to the vehicle.

10-12. Turbines. The turbine is designed to extract the kinetic energy (energy due to motion) from the expanding gases that flow from the combustion chamber. This kinetic energy then is converted into shaft horsepower to drive the compressor and engine accessories. Most of the energy obtained from the products of combustion (approximately 75 percent) is used to drive the compressor. The remaining 25 percent is utilized to power additional components such as oiling system and hydraulic systems. Additional power turbines are used to extract residual energy from the moving gases to provide vehicular power. Turbines can be divided into two basic types: radial inflow and axial flow.

a. Radial Inflow. This type of turbine (fig. 10-12) is similar to the centrifugal compressor in design and construction. Radial inflow operates as the inlet gases pass through openings that direct the gases onto the blades at the base of the compressor. The gas then acts against the blades of the turbine to produce the rotational effect. The gases then are exhausted at the top of the turbine, parallel to the axis of rotation. Despite its simplistic design and durability, the radial inflow turbine generally is limited to use in smaller engines.

b. Axial Flow. The axial flow turbine (fig. 10-13) is composed of two main elements: a set of stationary vanes and a turbine rotor or rotors. The axial flow turbine rotors are categorized into two basic types: impulse and reaction. The modern turbine consists of a combination of these two called the impulse-reaction turbine. Each is discussed below. As the name implies, the axial flow turbine wheel extracts kinetic energy from the moving gases that flow in a relatively straight line, parallel to the axis of rotation. The turbine wheel is used as the rotating element. Stationary vanes are used to deliver the gas to the next stage in the most efficient way possible.

(1) *Impulse Turbine.* The construction of the impulse turbine is illustrated in figure 10-14. In this configuration the area of the inlet and exit of the turbine blades are made equal. Thus, the velocity of the gas entering the blade is equal to the exiting velocity (minus frictional losses). The blades are designed in such a way that the high-velocity gases concentrate their energies on the center of the blade. The gases then bounce off the

TA233610

221

BEST COPY AVAILABLE

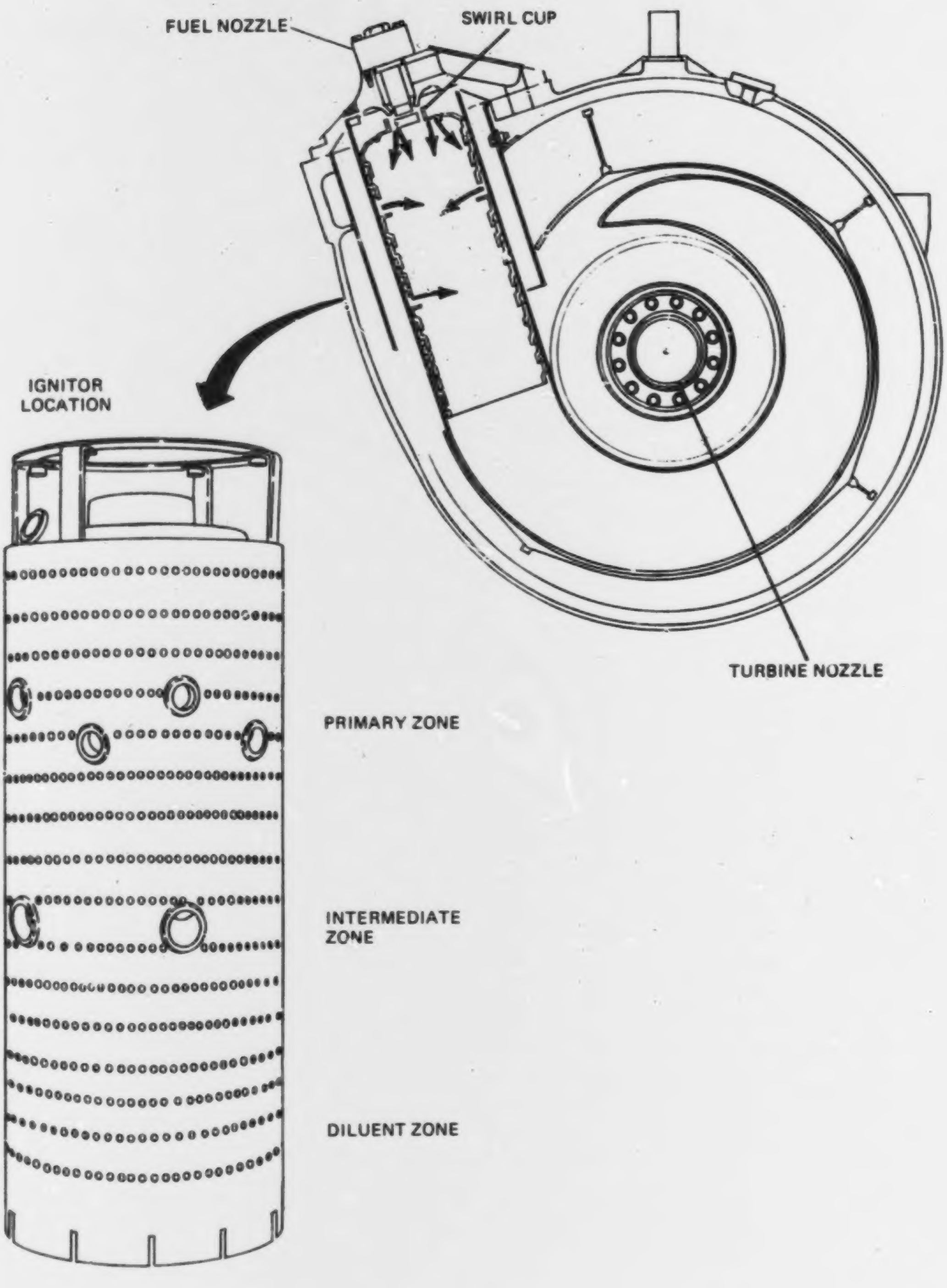

FUEL NOZZLE
SWIRL CUP
IGNITOR LOCATION
TURBINE NOZZLE
PRIMARY ZONE
INTERMEDIATE ZONE
DILUENT ZONE

Figure 10-9. Combustion Chamber.

TA233511

225

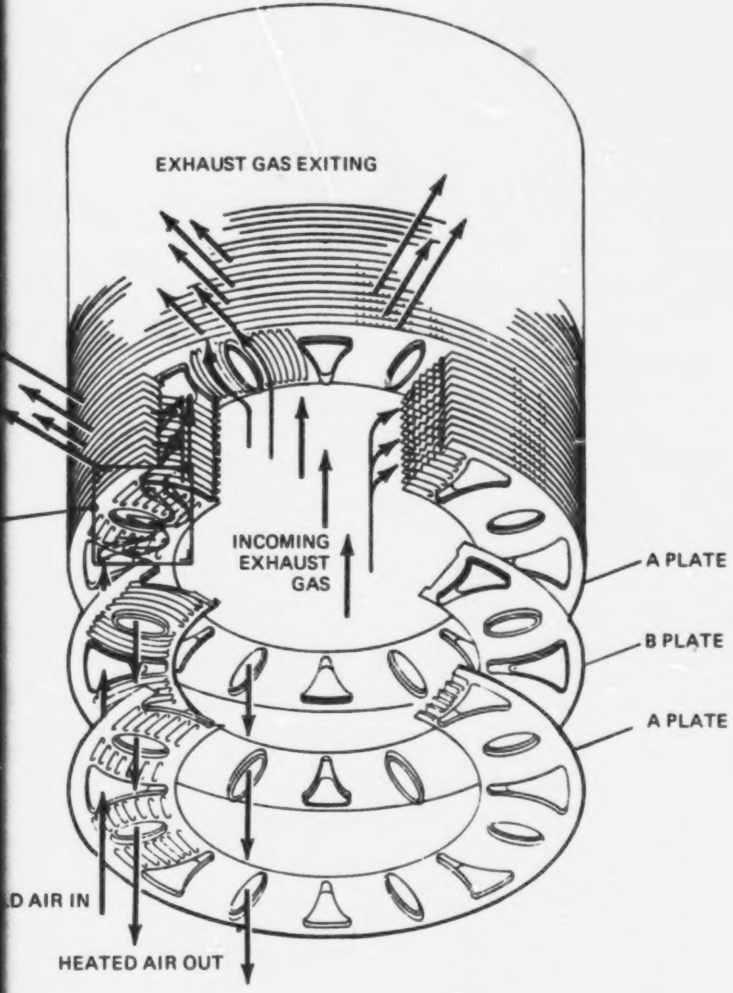


Figure 10-10. Typical Recouperator.

o the approach angle
force required to

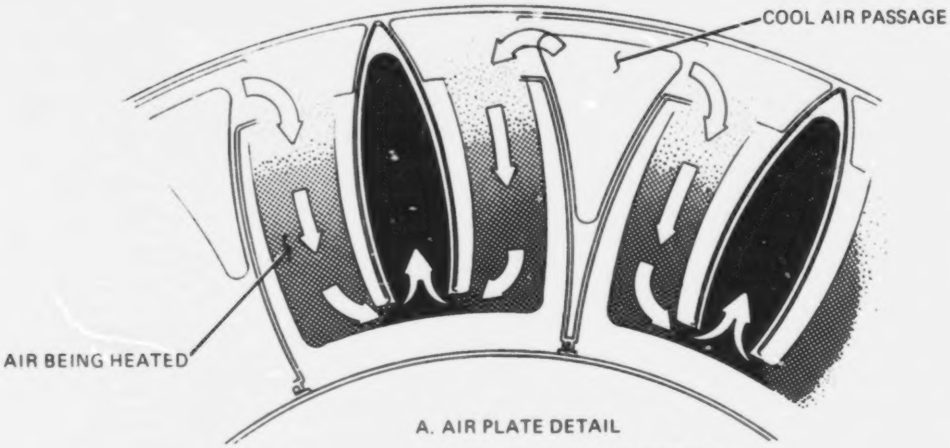
action turbine oper-
ssure principle much
e (fig. 10-15). As the
passageway on the
e in velocity and a
erienced. The result
eel in the direction of
turbine wheel, there-
tively high entrance
e turbine.

The impulse-
mbination of both the

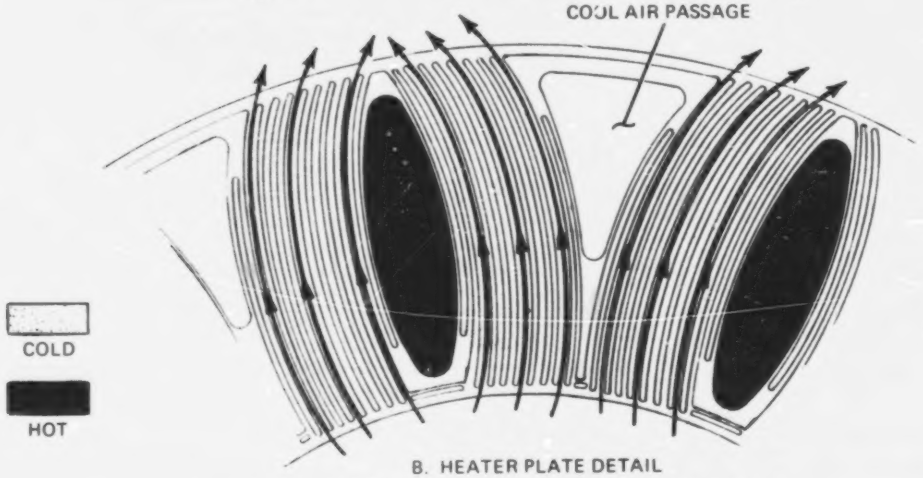
impulse and reaction design (fig. 10-16). The larger circumference of the assembly at the ends of the turbine blades requires the tips to travel at a faster rate of speed than the roots to obtain the same degree of rotation. The impulse-reaction type blade uses this concept to equalize the velocities of the gases exiting the root and tip of the turbine wheel. This type is designed so that the base of the blade is an impulse design and the tip is a reaction design. This provides an equal pressure distribution across the blade and, therefore, an efficient turbine blade. The impulse-reaction turbine blade is used almost exclusively in modern turboshaft engines.

c. *Construction.* Turbines operate at speeds ranging from approximately 8000 to 60,000 rpm,

TA233512


COOL AIR PASSAGE
AIR BEING HEATED

A. AIR PLATE DETAIL


COOL AIR PASSAGE
COLD
HOT

B. HEATER PLATE DETAIL

Figure 10-11. Recouperator Plate Detail.

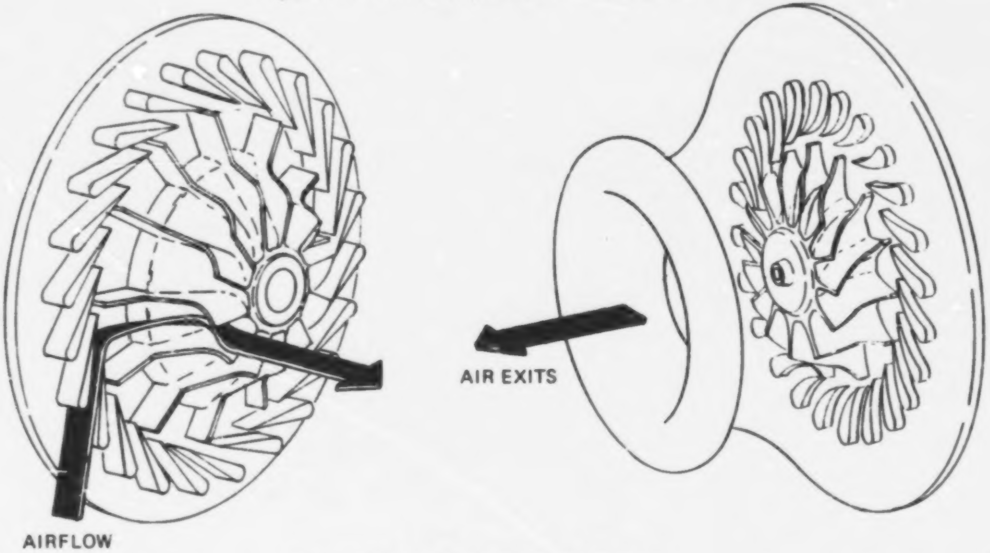

AIR EXITS
AIRFLOW

Figure 10-12. Radial Inflow Turbine.

TA233513

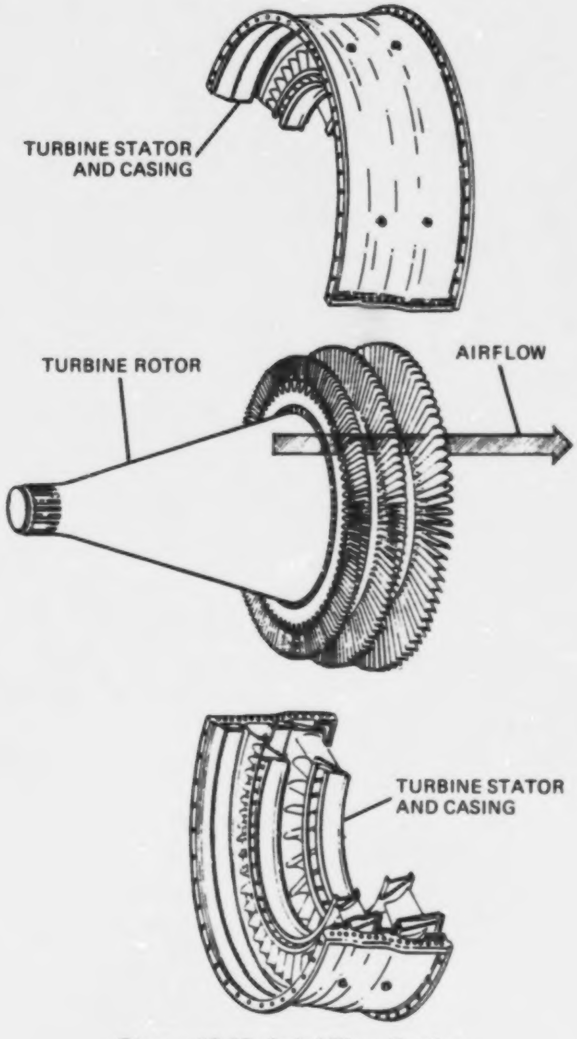

TURBINE STATOR AND CASING
TURBINE ROTOR
AIRFLOW
TURBINE STATOR AND CASING

Figure 10-13. Axial Flow Design.

depending on engine size. These high rotational speeds induce high-stress factors, which must be overcome for safe and efficient operation. The turbine is constructed of a disk and blades, each of which is carefully balanced and weighed. The blades (sometimes called buckets) are attached to the disk by a fir tree design (fig. 10-17). This design provides for different rates of expansion between blade and disk. The blades are attached axially by fasteners or rivets (fig. 10-17). Turbine blades can be open at the ends or constructed to form a shroud. The shroud is more desirable because of added strength and additional air control. Turbine temperature must be monitored closely during operation. To exceed the maximum operating temperature could result in changing the temper of the blades. This condition can change the pitch of the blades and render the engine less efficient and dangerous to operate.

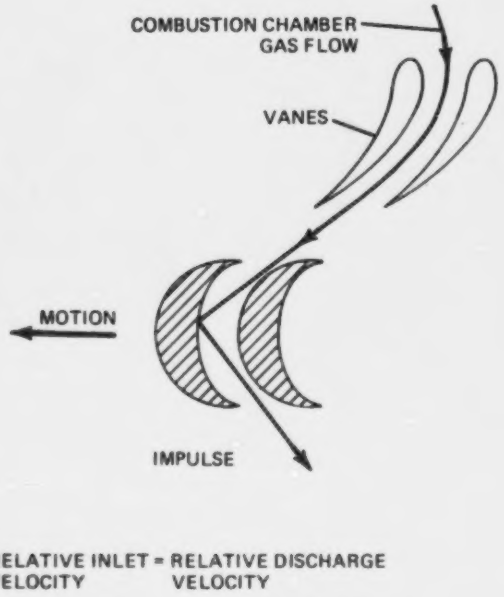

COMBUSTION CHAMBER GAS FLOW
VANES
MOTION
IMPULSE
RELATIVE INLET VELOCITY = RELATIVE DISCHARGE VELOCITY

Figure 10-14. Impulse Turbine.

10-13. Exhaust. The exhaust gases pass radially outward through the recouperator core into a collection plenum that is connected to the vehicle exhaust duct.

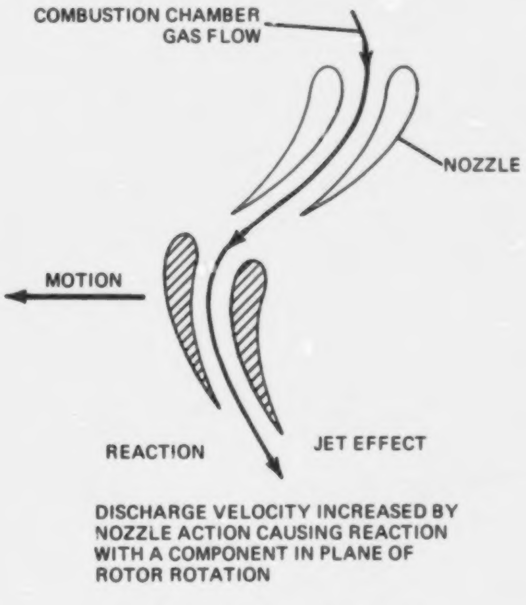

COMBUSTION CHAMBER GAS FLOW
NOZZLE
MOTION
REACTION
JET EFFECT
DISCHARGE VELOCITY INCREASED BY NOZZLE ACTION CAUSING REACTION WITH A COMPONENT IN PLANE OF ROTOR ROTATION

Figure 10-15. Reaction Turbine.

TA233514

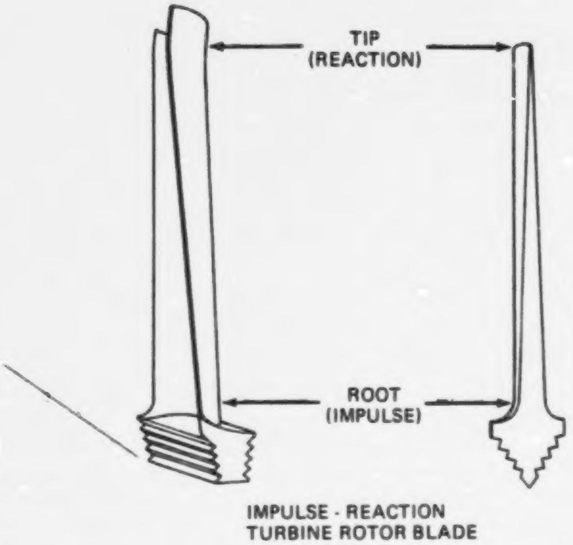

TIP
(REACTION)
ROOT
(IMPULSE)
IMPULSE - REACTION
TURBINE ROTOR BLADE

Figure 10-16. Impulse-Reaction Turbine Blade.

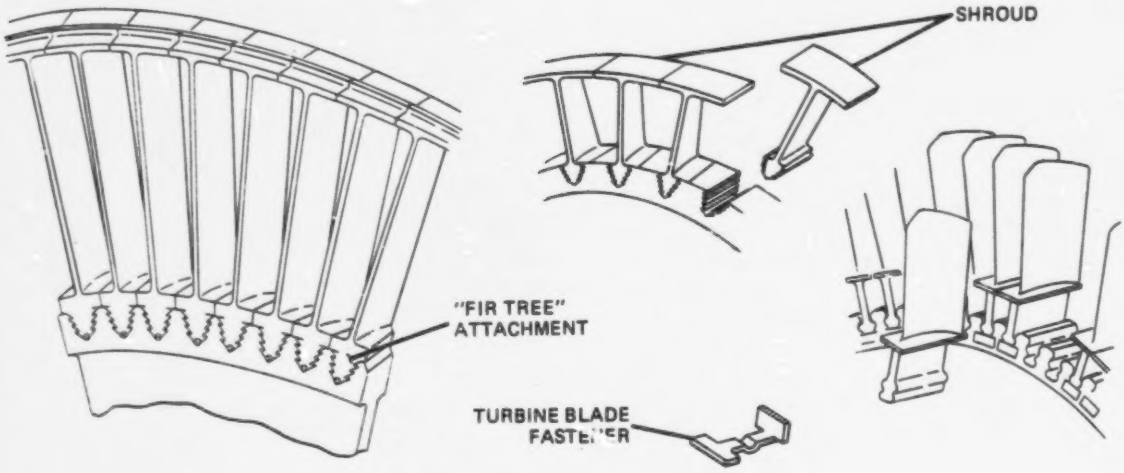

SHROUD
"FIR TREE"
ATTACHMENT
TURBINE BLADE
FASTENER

Figure 10-17. Turbine Construction.

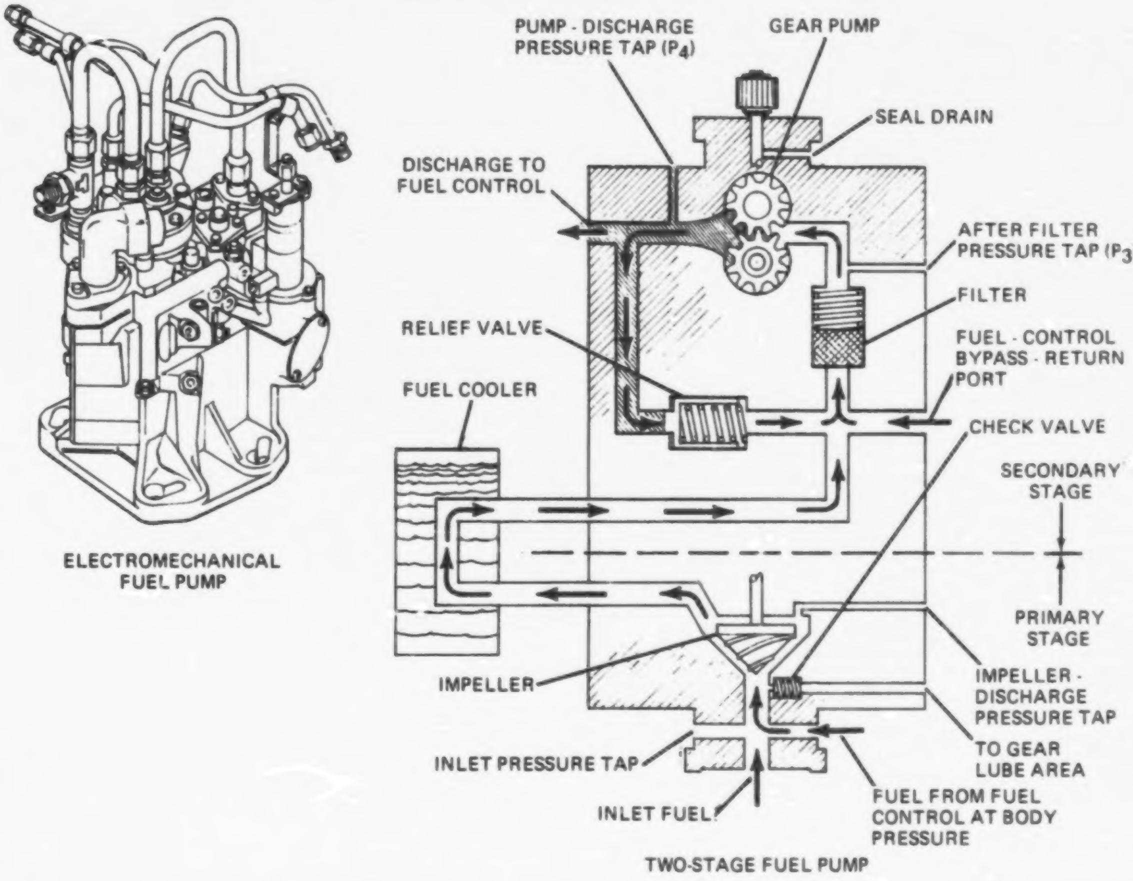
TA233515

Section IV. FUEL SYSTEM

10-14. Requirements. The fuel system is designed to provide the engine with the proper amount of fuel under all operating conditions. The fuel systems incorporated on gas turbine engines range from simple valves to complex microprocessor control assemblies. The fuel control system can receive inputs from one or two sources on some models, while other systems monitor multiple engine variables. Basically, these fuel systems are categorized into either a hydromechanical or electronic group.

10-15. Fuel Pumps. Fuel pumps are used to pressurize the fuel prior to injection into the combustion chamber. Gear pumps (para 20-4) generally are used to generate the fluid pressure required for operation. Some pumps are designed as a two-stage configuration. In this design an impeller is used for the first-stage pressure increase. The fuel then is routed to a heat exchanger to cool the pressurized fuel. A gear pump then is used for the final pressure increase. A pressure relief valve also is used to limit the amount of pressure the pump develops at high speed (fig. 10-18).

10-16. Fuel Nozzles. Fuel nozzles are used to induce fuel into the combustion chamber. They are designed to produce an accurately shaped spray pattern and maintain combustion during varying engine operating conditions. Injection nozzles generally are either the single or dual spray pattern design (fig. 10-19). The single nozzle provides one spray pattern of fuel under all conditions (fig. 10-19). The dual nozzle is designed to provide a single spray pattern at low


PUMP - DISCHARGE PRESSURE TAP (P_4)
GEAR PUMP
SEAL DRAIN
DISCHARGE TO FUEL CONTROL
AFTER FILTER PRESSURE TAP (P_3)
FILTER
RELIEF VALVE
FUEL - CONTROL BYPASS - RETURN PORT
FUEL COOLER
CHECK VALVE
SECONDARY STAGE
PRIMARY STAGE
IMPELLER
IMPELLER - DISCHARGE PRESSURE TAP
TO GEAR LUBE AREA
INLET PRESSURE TAP
INLET FUEL
FUEL FROM FUEL CONTROL AT BODY PRESSURE

ELECTROMECHANICAL FUEL PUMP

TWO-STAGE FUEL PUMP

Figure 10-18. Gas Turbine Fuel Pumps.

TA233516

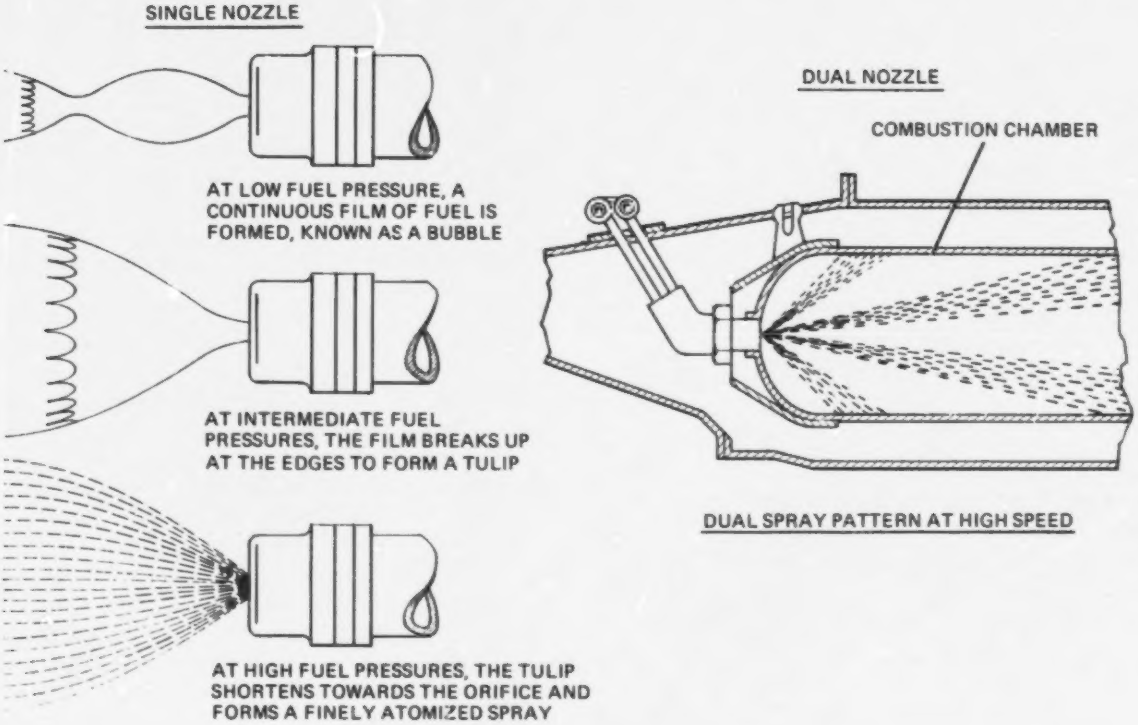

SINGLE NOZZLE
AT LOW FUEL PRESSURE, A CONTINUOUS FILM OF FUEL IS FORMED, KNOWN AS A BUBBLE
AT INTERMEDIATE FUEL PRESSURES, THE FILM BREAKS UP AT THE EDGES TO FORM A TULIP
AT HIGH FUEL PRESSURES, THE TULIP SHORTENS TOWARDS THE ORIFICE AND FORMS A FINELY ATOMIZED SPRAY
DUAL NOZZLE
COMBUSTION CHAMBER
DUAL SPRAY PATTERN AT HIGH SPEED

Figure 10-19. Fuel Injection Nozzles.

speeds also, but as speed increases, secondary parts are opened, allowing additional fuel to enter the combustion chamber. This feature provides the engine with the proper air-fuel ratio over a broad band of operating conditions.

Section V. LUBRICATION SYSTEM

10-17. Requirements. The lubrication system is designed to clean, cool, and lubricate the internal components of the engine. While each lubrication system is designed for a particular engine, certain components are common on most systems. A wide variety of operating temperatures makes the design of the lubrication system even more difficult. Gas turbine engines operate in vehicles that can be exposed to temperatures as low as -60°F (-51.1°C), as well as internal temperatures as high as 400°F (204.4°C). One severe problem experienced with gas turbine engines occurs as the engine is stopped. A large amount of heat, stored in the turbine, then is transferred to the bearings. This phenomenon raises the temperature of the bearing much higher than that encountered during operation. The temperature of the lubricating oil, which is now stagnant around the bearing, also is greatly increased. Care must be taken in selecting an oil that will not break down under these severe conditions.

10-18. Lubrication Oils. Lubricating oils used in gas turbine engines must possess certain performance factors. Oils must resist foaming and provide a steady stream of oil to bearings. This ensures proper lubrication and cooling under all operating conditions. Mineral oil and synthetic oils commonly are used for lubricating purposes in turbine engines, as discussed below.

a. Mineral Oils. Mineral oils generally are used in smaller, low-power engines and where temperatures do not reach extremes. These oils generally are not used because they are incapable of providing satisfactory performance at both very low and very high operating temperatures. They have been known to be extremely thick at low

TA233517

231

temperatures and break down under adverse conditions.

b. Synthetic Oils. Synthetic oils are commonly used as the lubrication medium. They are treated with the proper compounds to allow them to withstand extreme operating conditions. More information on synthetic oils can be found in chapter 8.

10-19. Lubrication System Components. The construction and operation of components common to most gas turbine engines is discussed below.

a. Oil Tanks. Oil tanks are used for onboard storage of oil for the lubrication system. They usually are made of welded sheet aluminum or steel. Cooling fins sometimes are used to provide additional heat transfer through the sides of the tank. Oil tanks sometimes are pressurized to ensure a constant supply of oil to the pressure pump. A typical oil tank with dipstick is shown in figure 10-20.

b. Pressure Pumps. Both gear- and rotor-type pumps are used to generate fluid pressure for the lubrication system. Both types are discussed in paragraphs 20-4 and 20-5.

c. Scavenger Pumps. These pumps are used to collect oil that has passed through the components to be lubricated. The pumps then pressurize the oil to force it to the next stage in the lubrication system. Both gear and rotor pumps generally are used for scavenging operations.

d. Filters. Oil filters are used to help remove impurities from the oil. They are serviced at regular intervals. Three basic types of oil filters are used in turbine engines: screen, screen disk, and cartridge. The screen and screen-disk type filters are cleaned and reused while the cartridge type is removed and replaced by a new one.

e. Oil Coolers. Oil coolers are designed to transfer unwanted heat from lubricating oil to another medium, usually fuel or a passing airstream. The fuel-oil cooler uses a high volume of fuel with respect to oil passing through the cooler to transfer unwanted heat from the oil to fuel. A typical fuel-oil cooler is illustrated in figure 10-21. The air-oil cooler is the same type as the one discussed in paragraph 8-14.

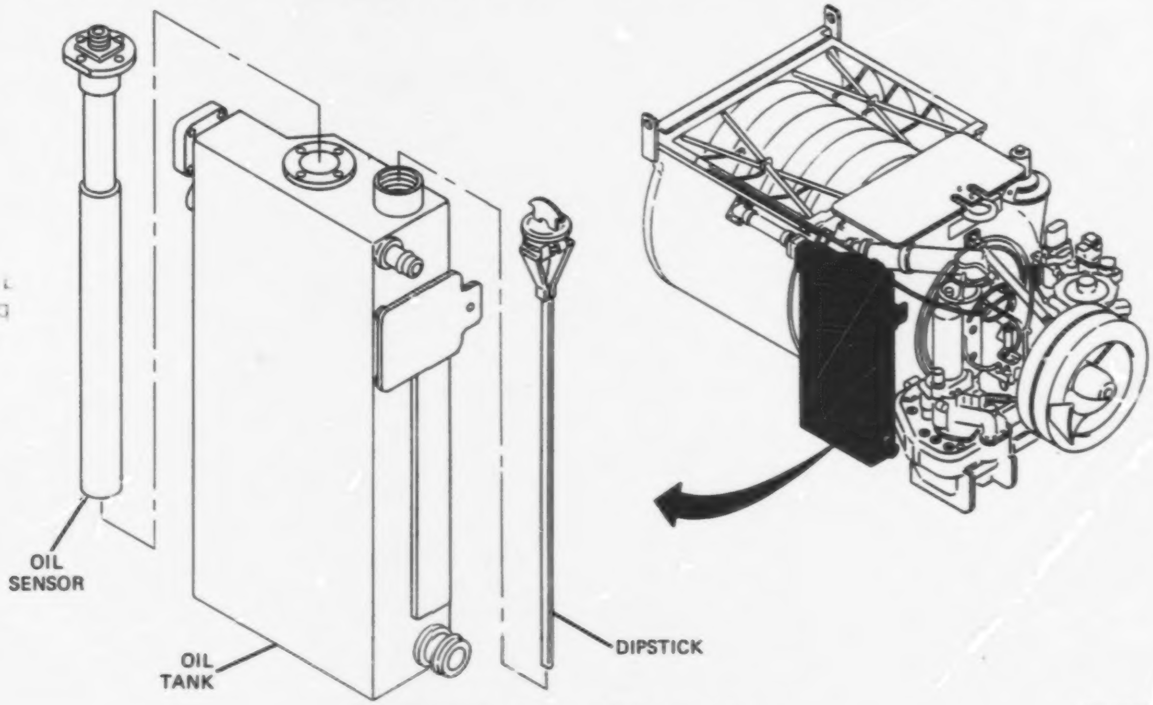


Figure 10-20. Typical Oil Storage Tank.

TA233518

232

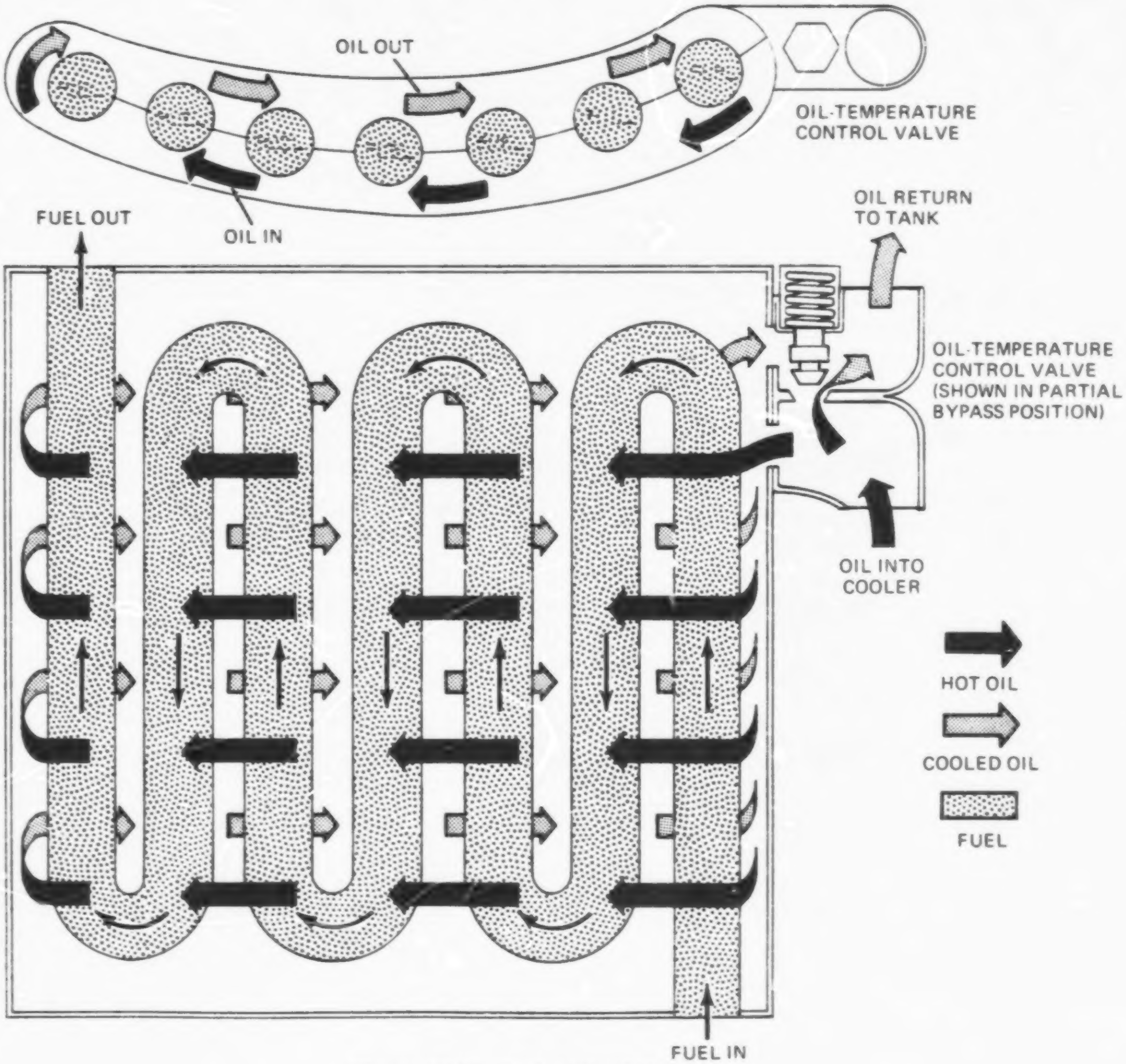

OIL OUT
OIL-TEMPERATURE CONTROL VALVE
FUEL OUT
OIL IN
OIL RETURN TO TANK
OIL-TEMPERATURE CONTROL VALVE (SHOWN IN PARTIAL BYPASS POSITION)
OIL INTO COOLER
HOT OIL
COOLED OIL
FUEL
FUEL IN

Figure 10-21. Typical Fuel-Oil Cooler.

Section VI. ELECTRICAL SYSTEM

10-20. Introduction. The electrical system provides circuitry to facilitate ignition, starting, and operation of all engine-oriented electrical monitoring devices. Discussion of all major components in the gas turbine electrical system is found below.

10-21. Ignition System. The ignition process in the gas turbine engine is a continuous, self-sustaining process. The ignition system basically is used only when first starting the engine. Once the combustion process has begun, the ignition system is turned off and the flame is sustained by self-generation. An igniter (fig. 10-22) is used, in place of a spark plug, in gas turbine engines. The igniters tend to wear out faster, in comparison to regular spark plugs; however, one must take into account the relative time frame the ignition systems are activated to determine the actual lifespan of each component. The igniter receives its power from a capacitor-type ignition system. This system provides a high-energy, high-temperature spark, ideal for application in the gas turbine engine. A typical igniter and ignition system is illustrated in figure 10-22.

TA233519

233

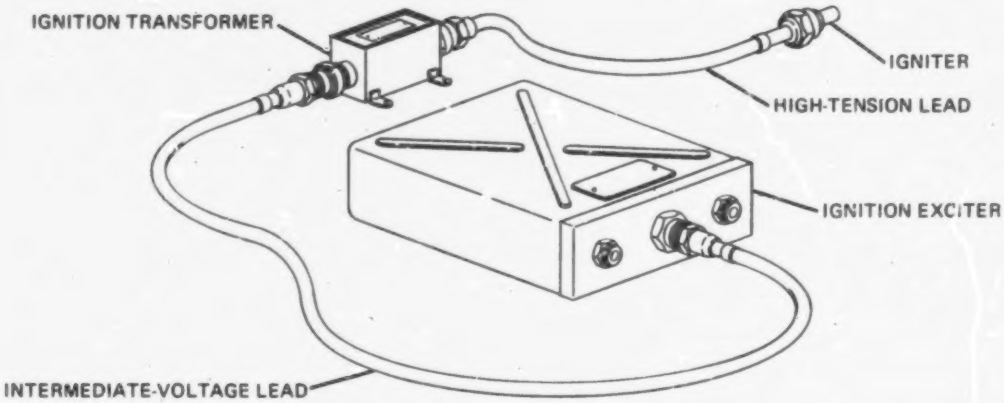

IGNITION TRANSFORMER
IGNITER
HIGH-TENSION LEAD
IGNITION EXCITER
INTERMEDIATE-VOLTAGE LEAD

Figure 10-22. Typical Ignition System.

10-22. Starting System. The starting system is designed to rotate the compressor up to idle speed. At this time the engine will continue operation by itself and the starting mechanism can be disengaged. Electric motors generally are used for starting purposes in gas turbine engines. The majority of electric starters on gas turbine engines operate on 24 vdc. They are series wound (para 14-3c) to provide high starting torque. Some models draw in excess of 1000 amperes during operation. Some units automatically engage the ignition system as the starter is engaged. A typical electric starter is illustrated in figure 10-23.

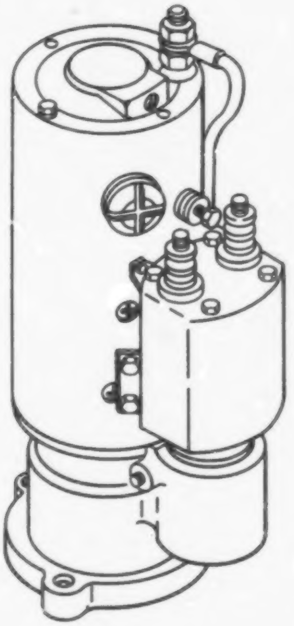


Figure 10-23. Typical Electric Starter.

TA233520

231

PART THREE

ELECTRICAL SYSTEMS AND RELATED UNITS

CHAPTER 11

BASIC PRINCIPLES OF ELECTRICITY

Section I. ELECTRICITY

11-1. Composition of Matter.

a. To understand electricity, first study matter, the name for all material substances. Everything (solids, liquids, and gases) is made up of tiny particles known as atoms. These atoms combine in small groups of two or more to form molecules. Air is made up of molecules. These molecules are made up of atoms, and these atoms can be further subdivided. When atoms are divided, smaller particles are created, some of which have positive and others, negative electrical charges. Atoms of different materials are discussed below.

b. There are over 100 different basic materials in the universe. These basic materials are called elements. Iron is one element; copper, aluminum, oxygen, hydrogen, and mercury are other elements. An element gets its name from the fact that it cannot be broken down easily into simpler (or more elemental) substances. In other words, more than 100 basic elements are the building materials from which the universe is made. If any one of these elements is studied closely, it is obvious that it is made up of those same basic particles having positive and negative electrical charges as discussed above.

c. The basic particles that make up all the elements, and thus all the universe, are called protons, electrons, and neutrons. A proton is a basic particle having a single positive charge; a group of protons produces a positive electrical charge. An electron is a basic particle having a single negative charge; therefore, a group of electrons produces a negative electrical charge. A neutron is a basic particle having no charge; a group of neutrons, therefore, would have no charge.

d. Examine the construction of atoms of the various elements, starting with the simplest of all, hydrogen. The atom of hydrogen consists of one proton, around which is circling one electron (fig. 11-1). There is an attraction between the two particles, because negative and positive electrical charges always attract each other.

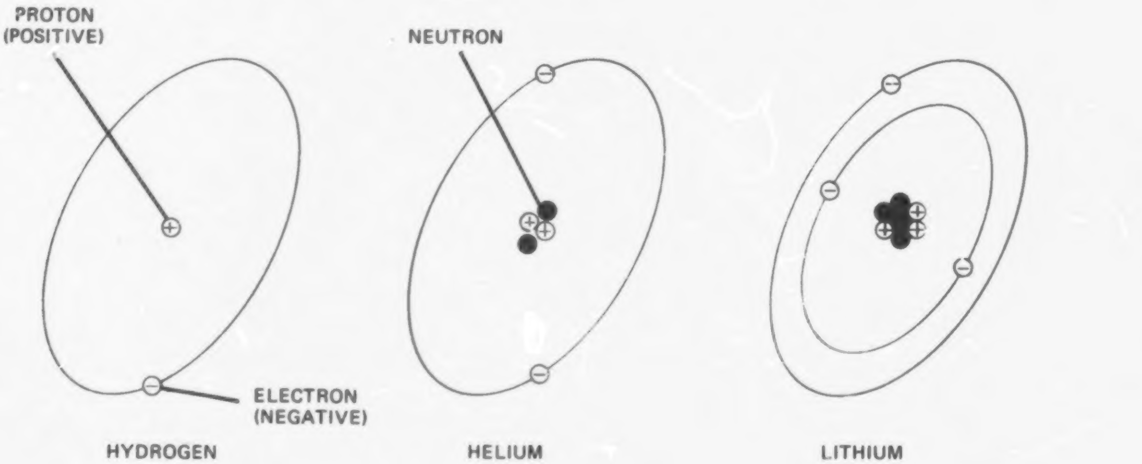


Figure 11-1. Composition of Matter.

TA233521

235

BEST COPY AVAILABLE

Opposing the attraction between the two particles, and thus preventing the electron from moving into the proton, is the centrifugal force on the electron caused by its circular path around the proton. This is the same sort of balance achieved if a ball tied to a string was whirled in a circle in the air. The centrifugal force exerted tries to move the ball out of its circular path, and is balanced by the string (the attractive force). If the string should break, the centrifugal force would cause the ball to fly away. Actually, this is what happens at times with atoms. The attractive force between the electron and proton sometimes is not great enough to hold the electron in its circular path, and the electron gets away.

e. A slightly more complex atom is shown in figure 11-1. This is an atom of helium. Notice that there are now two protons in the center and that two electrons are circling around the center. Because there is an additional proton in the center, or nucleus, of the atom, an electron must be added so as to keep the atom in electrical balance. Notice also that there are two additional particles in the nucleus; these are called neutrons. Neutrons are necessary in order to overcome the tendency of the two protons to move apart from each other. For, just as unlike electrical charges attract, so do like electrical charges repel. Electrons repel electrons. Protons repel protons, except when neutrons are present. Though neutrons have no electrical charge, they do have the ability to cancel out the repelling forces between protons in an atomic nucleus and thus hold the nucleus together.

f. A still more complex atom is shown in figure 11-1. This is an atom of lithium, a light, soft metal. Note that a third proton has been added to the nucleus and that a third electron is now circling around the nucleus. There also are two additional neutrons in the nucleus; these are needed to hold the three protons together. The atoms of other elements can be seen in a similar manner. As the atomic scale increases in complexity, protons and neutrons are added one by one to the nucleus, and electrons to the outer circles. After lithium comes beryllium with four protons and five neutrons, boron with five protons and five neutrons, carbon with six and six, nitrogen with seven and seven, oxygen with eight and eight, and so on. In each of these, there are normally the same number of electrons circling the nucleus as there are protons in the nucleus.

11-2. Composition of Electricity (Fig. 11-2).

a. When there are more than two electrons in an atom, they will move about the nucleus in different size orbits. These orbits are referred to as shells. The innermost shells of the atom contain electrons that are not easily freed and are referred to as bound electrons. The outermost shell will contain what is referred to as free electrons. These free electrons differ from bound electrons in that they can be moved readily from their orbit.

b. If a point that has an excess of electrons (positive) is connected to a point that has a shortage of electrons (negative), a flow of electrons (electrical current) will flow through the connector (conductor) until an equal electric charge exists between the two points.

11-3. Electron Theory of Electricity (Fig. 11-2). A charge of electricity is formed when numerous electrons break free of their atoms and gather in one area. When the electrons begin to move in one direction (as along a wire, for example), the effect is a flow of electricity or an electric current. Actually, electric generators and batteries could be called electron pumps, because they remove electrons from one part of an electric circuit and concentrate them in another part of the circuit. For example, a generator takes electrons away from the positive terminal and concentrates them at the negative terminal. Because the electrons repel each other (like electrical charges repel), the electrons push out through the circuit and flow to the positive terminal (unlike electrical charges attract). Thus, we can see that an electric current is actually a flow of electrons from negative to positive.

This is just the reverse of the old idea of current flow. Before scientists understood what electric current was, they assumed that the current flowed from positive to negative. However, their studies showed that this was wrong, because they learned that the current is electron movement from negative (concentration of electrons) to positive (lack of electrons).

11-4. Conductors and Insulators (Fig. 11-3).

a. *General.* Any material that will allow electric current to flow through it is an electrical

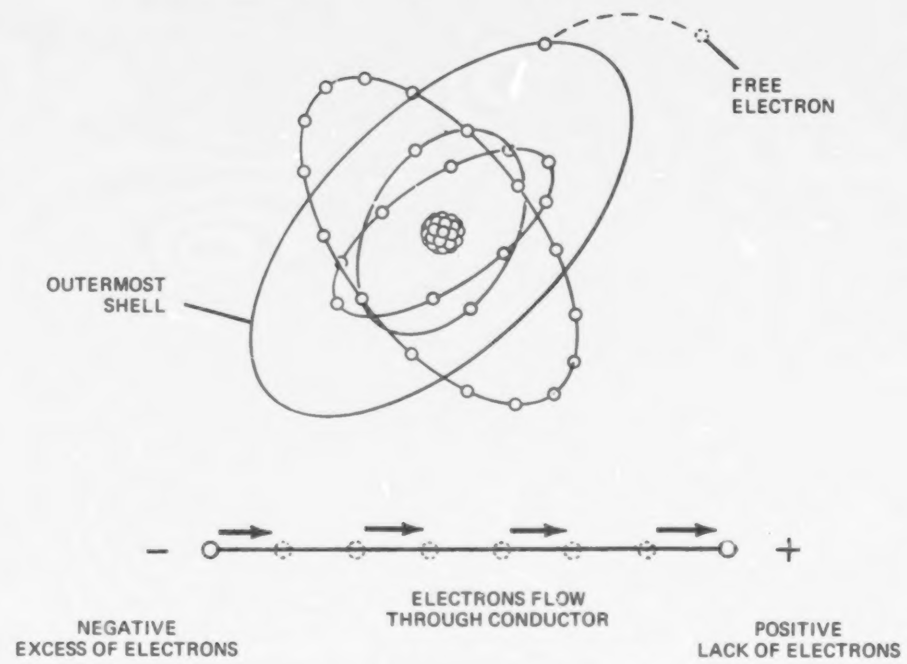
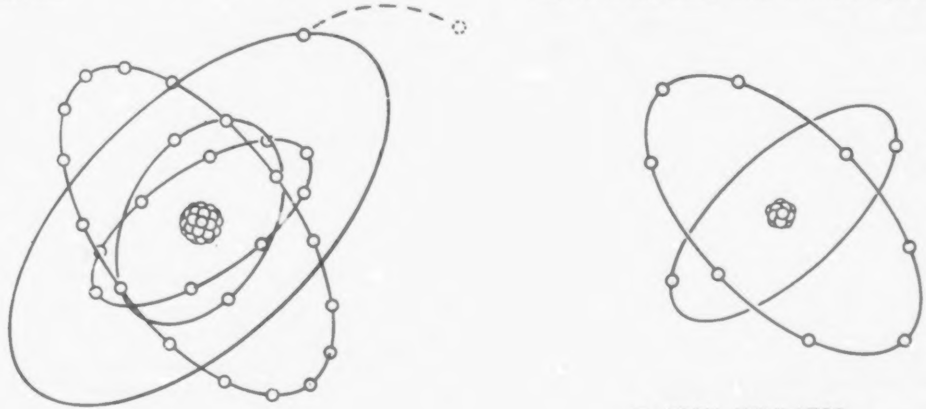

FREE ELECTRON
OUTERMOST SHELL
−
+
ELECTRONS FLOW THROUGH CONDUCTOR
NEGATIVE EXCESS OF ELECTRONS
POSITIVE LACK OF ELECTRONS

Figure 11-2. Composition of Electricity.

conductor. Any material that blocks electric current flow is an electrical insulator. Conductors are used in automotive equipment to carry electric current to all of the electrical equipment. Insulators also are necessary to keep the electric current from taking a shorter route instead of going to the intended component. The electrical properties of a substance depends mainly on the number of electrons in the outermost orbits of its atoms that cannot, at any time, contain more than eight electrons.

b. Conductors (A, Fig. 11-3). Whenever there are less than four electrons in the outer orbits of the atoms of a substance, these electrons will tend to be free. This will cause the substance to permit free motion of electrons, making it a conductor. Electrical energy is transferred through conductors by means of the movement of free electrons that migrate from atom to atom within the conductor. Each electron moves a short distance to the neighboring atom, where it replaces one or more electrons by forcing



A. COPPER - CONDUCTOR
(ONE FREE ELECTRON)

B. NEON - INSULATOR
(OUTER SHELL FULL, NO FREE ELECTRONS)

Figure 11-3. Conductors and Insulators.

TA233522

them out of their orbits. The replaced electrons repeat this process in nearby atoms until the movement is transmitted throughout the entire length of the conductor, thus creating a current flow. Copper is an example of a good conductor because it only has one free electron. This electron is not held very strongly in its orbit and can get away from the nucleus very easily. Silver is a better conductor of electricity but it is too expensive to be used in any great quantity. Because of this, copper is the conductor used most widely in automotive applications.

c. Insulators (B, Fig. 11-3). Whenever there are more than four electrons in the outer orbits of the atoms of a substance, these electrons will tend to be bound, causing restriction of free electron movement, making it an insulator. Common insulating substances in automotive applications are rubber, plastic, Bakelite, varnish, and fiberboard.

Section II. SEMICONDUCTOR DEVICES

11-5. Fundamental Principles.

a. Description. Paragraph 11-4 explains that any substance whose atoms contain less than four electrons in their outermost orbits is classified as an electrical conductor. It also is explained that any substance whose atoms contain more than four electrons in their outermost orbits is classified as an electrical insulator. A special case exists, however, when a substance contains four electrons in the outermost orbits of its atoms. This type of substance is known as a semiconductor and is the basis for all modern electronic equipment. The most popular of all semiconductors is silicon.

b. Characteristics of Semiconductors. In its pure state, silicon is neither a good conductor or insulator. But by processing silicon in the following ways, its conductive or insulative properties can be adjusted to suit just about any need.

(1) When a number of silicon atoms are jammed together in crystalline (glasslike) form, they form a covalent (sharing) bond. Therefore, the electrons in the outer ring of one silicon atom join with the outer ring electrons of other silicon atoms, resulting in a sharing of outer ring electrons between all of the atoms. It can be seen in figure 11-4 that covalent sharing gives each atom eight electrons in its outer orbit, making the orbit complete. This makes the material an insulator because it contains more than four electrons in its outer orbit.

(2) When certain materials such as phosphorus are added to the silicon crystal in highly controlled amounts the resultant mixture becomes a conductor (fig. 11-5). This is because phosphorus, which has five electrons in forming a covalent bond with silicon (which has four electrons in its outer shell), will yield one free electron per molecule, thus making the material an electrical conductor. The process of adding impurities to a semiconductor is called doping. Any semiconductor material that is doped to yield free electrons is called N-type material.

(3) When boron, which has three electrons in its outer ring, is used to dope the silicon crystal, the resultant covalent bonding yields seven electrons in the outer shell. This leaves an opening for another electron and is illustrated in figure 11-6. This space is called a hole and can be considered a positive charge just as the extra electrons that exist in N-type semiconductor material are considered a negative charge. Materials that have holes in their outermost electron shells are called positive or P-type materials. In order to understand the behavior of P-type semiconductors, it is necessary to look upon the hole as a positive current carrier, just as the free electron in N-type semiconductors are considered negative current carriers. Just as electrons move through N-type semiconductors, holes move from atom-to-atom in P-type semiconductors. Movement of holes through P-type semiconductors, however, is from the positive terminal to the negative terminal. For this reason, any circuit analysis of solid-state circuitry is done on the basis of positive to negative (conventional) current flow.

c. Hole Movement Theory (Fig. 11-7). When a source voltage, such as a battery, is connected to N-type material, an electric current will flow through it. The current flow in the N-type semiconductor consists of the movement of free

238

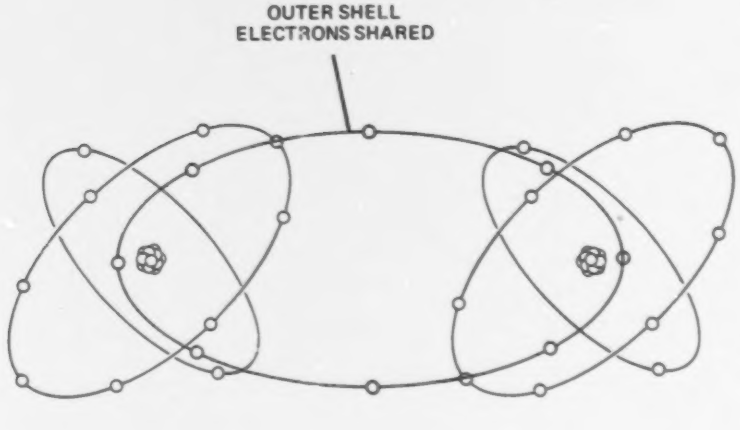


Figure 11-4. Covalent Bonding of Silicon.

electrons, the same as the current flow through a natural conductor such as copper. When a current source of sufficient voltage is connected across a P-type material, an electric current will also flow through it, but any current flow in a P-type semiconductor is looked upon as the movement of positively charged holes. The holes appear to move toward the negative terminal as the electrons enter the material at the negative terminal, fill the holes, and then move from hole to hole toward the positive terminal. As is the case with N-type semiconductors, the movement of electrons through P-type semiconductors toward the positive terminal is motivated by the natural attraction of unlike charges.

11-6. Diodes (Fig. 11-8).

a. Purpose. A diode is a device that will allow current to pass through itself in only one direction. A diode can be thought of as an electrical checkvalve.

b. Construction. A diode is made by joining N-type material and P-type material together. The negative electrical terminal is located at the N-type material and the positive terminal is located on the P-type material.

c. Operation. When a diode is placed in a circuit, the N-material is connected to the

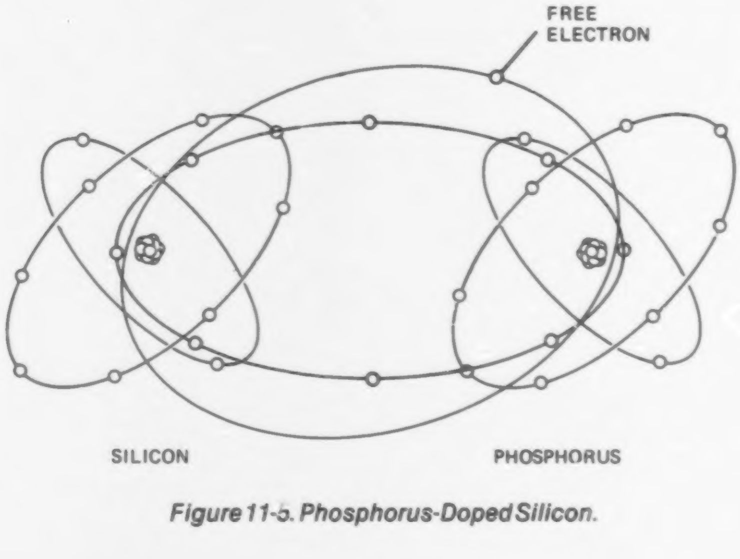


Figure 11-5. Phosphorus-Doped Silicon.

TA233523

239

BEST COPY AVAILABLE

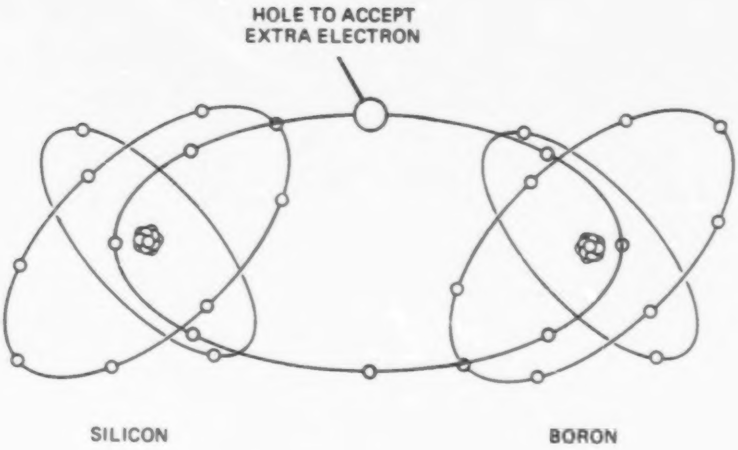


Figure 11-6. Boron-Doped Silicon.

negative side of the circuit and the positive side of the circuit is connected to the P-material. In this configuration, which is known as forward bias, the diode is a good conductor. This is because the positively charged holes in the P-type material move toward the junction with the negatively charged N-material so that electrons may cross the junction and fill these holes using them to move across the P-material. If the connections to the diode are reversed, current flow will be blocked. This configuration is known as reverse bias. When the diode is connected backwards, the positively charged holes are attracted away from the junction to the negative terminal and the free electrons in the N-material are attracted away from the junction to the positive terminal. Without the presence of holes at the junction, the electrons cannot cross it.

11-7. Zener Diodes (Fig. 11-9). The diode, as described in paragraph 11-6, is a semiconductor device that allows current to flow only in one direction. A zener diode, however, is a special type that allows reverse current to flow as long as the voltage is above a value that is built into the device when it is manufactured. As an example, a certain zener diode may not conduct current if the reverse bias voltage is below 6 volts. As the voltage increases to 6 volts or more, the diode suddenly will begin to conduct reverse bias current. This device is used in control circuits such as voltage regulators.

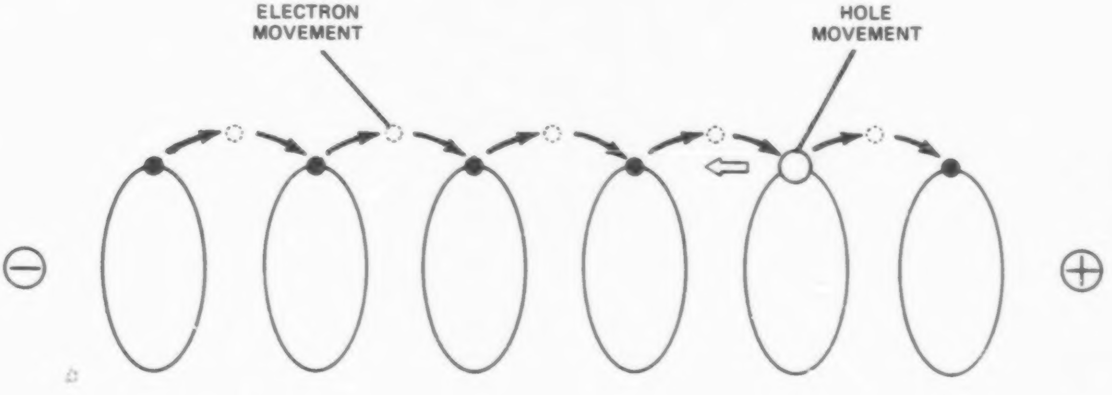
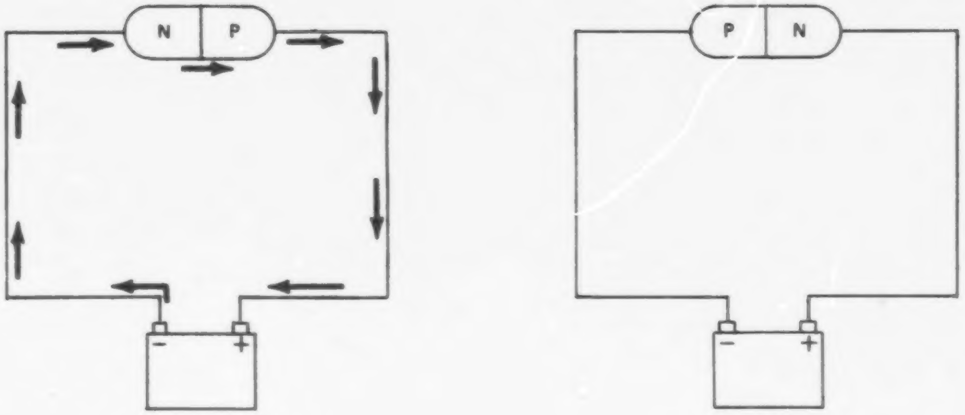


Figure 11-7. Hole Movement Theory.

TA233524

240

BEST COPY AVAILABLE



FORWARD BIASED
CURRENT FLOW

REVERSE BIAS
NO CURRENT FLOW

Figure 11-8. Diode Operation.

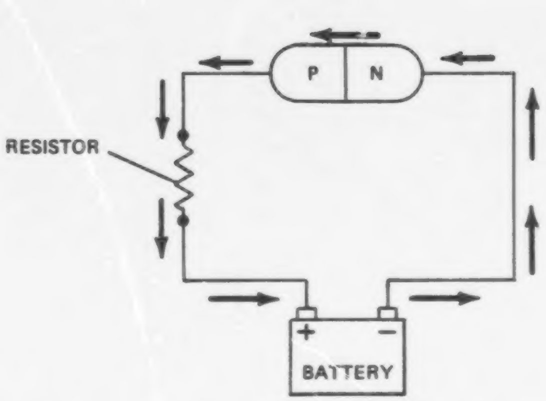
11-8. Transistors.

a. General (Fig. 11-10). Transistors, as they apply to automotive applications, are switching devices. They can switch large amounts of electric current on and off using relatively small amounts of electric current. Because transistors operate electronically, they last much longer than the relays they replace. This is because they have no contact points to burn. The major automotive applications of transistors are for electronic ignition systems and voltage regulators.

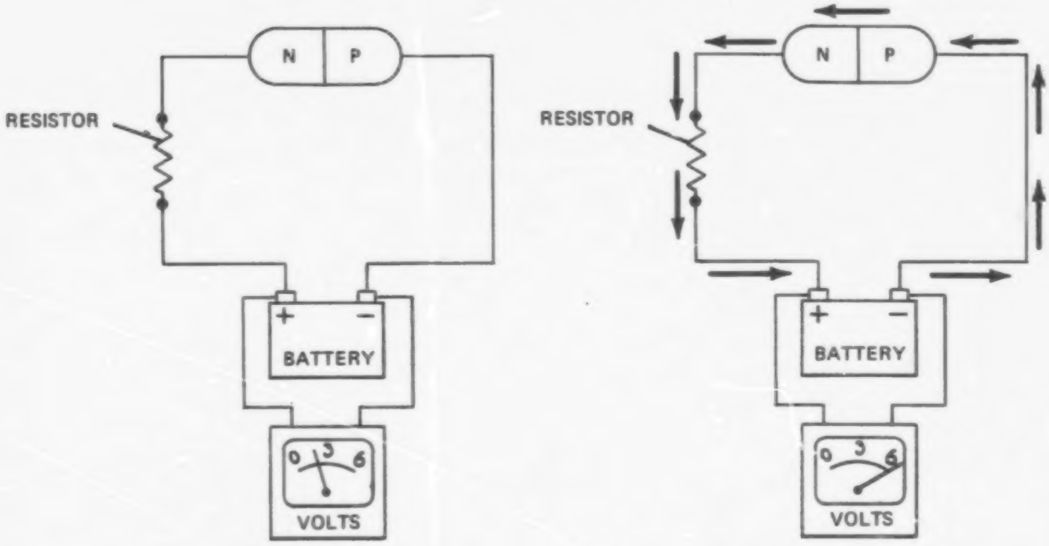
b. PNP Transistors (Fig. 11-11). The PNP transistor is the most common configuration in automotive applications. It is manufactured by sandwiching an N-type semiconductor element between two P-type semiconductor elements. A positive charge is applied to one of the P-type elements. This element is called the emitter. The other P-type element connects to the electrical component. This element is called the collector. The third element, which is in the middle, is made of N-type material and is called the base. The application of a low-current negative charge to the base will allow a heavy current to flow between the emitter and the collector. Whenever the current to the base is switched off, the current flow from the emitter to the collector is interrupted also.

c. NPN Transistors (Fig. 11-11). The NPN transistor is similar to the PNP transistor. The difference is that it is used in the negative side of the circuit. As the name NPN implies, the makeup of this transistor is two elements of N-type material (collector and emitter) with an element of P-type material (base) sandwiched in between. The NPN transistor will allow a high-current negative charge to flow from the collector to the emitter whenever a relatively low current positive charge is applied to the base.

TA233525


P
N
RESISTOR
+
−
BATTERY

FOWARD BIASED
CURRENT FLOW REGARDLESS
OF APPLIED VOLTAGE


N
P
RESISTOR
+
−
BATTERY
0
3
6
VOLTS
N
P
RESISTOR
+
−
BATTERY
0
3
6
VOLTS

REVERSE BIAS
NO CURRENT FLOW
BELOW 6 VOLTS

REVERSE BIAS
CURRENT FLOW BEGINS AS
APPLIED VOLTAGE REACHES 6

Figure 11-9. Zener Diodes Operation.

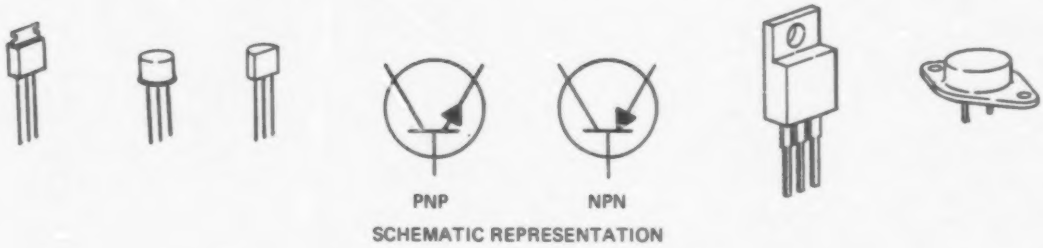
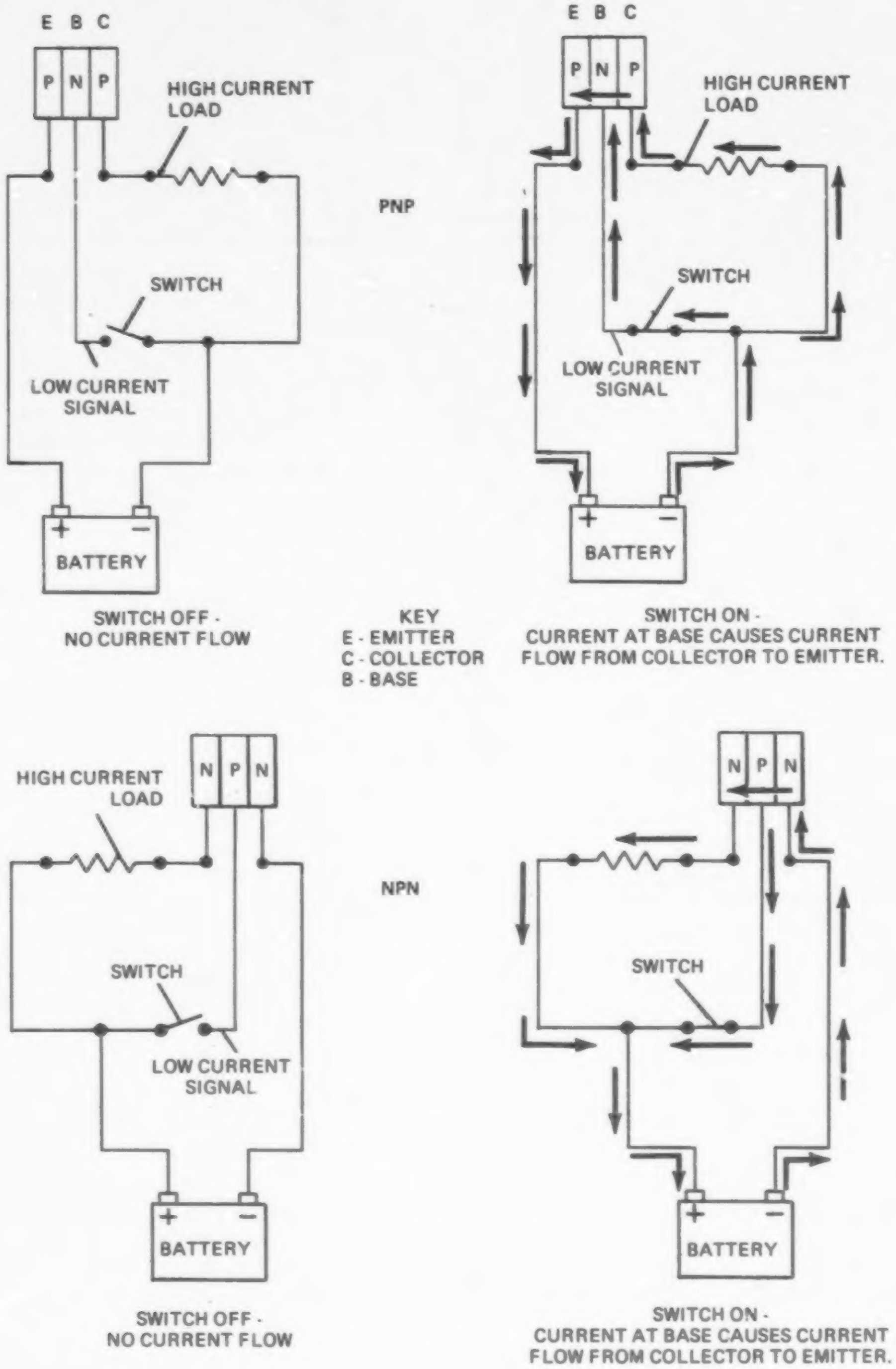

PNP
NPN
SCHEMATIC REPRESENTATION

Figure 11-10. Transistor Configurations.

TA233526


E B C
P N P
HIGH CURRENT LOAD
SWITCH
LOW CURRENT SIGNAL
BATTERY
+
−
PNP
E B C
P N P
HIGH CURRENT LOAD
SWITCH
LOW CURRENT SIGNAL
BATTERY
+
−
KEY
E - EMITTER
C - COLLECTOR
B - BASE
N P N
HIGH CURRENT LOAD
SWITCH
LOW CURRENT SIGNAL
BATTERY
+
−
NPN
N P N
SWITCH
BATTERY
+
−

SWITCH OFF - NO CURRENT FLOW

SWITCH ON - CURRENT AT BASE CAUSES CURRENT FLOW FROM COLLECTOR TO EMITTER.

SWITCH OFF - NO CURRENT FLOW

SWITCH ON - CURRENT AT BASE CAUSES CURRENT FLOW FROM COLLECTOR TO EMITTER.

Figure 11-11. Transistor Operation.

TA233527

Section III. ELECTRICAL MEASUREMENTS

11-9. Amperage (Current) and Voltage.

a. Amperes. Current flow, or electron flow, is measured in amperes. While it is normally considered that one ampere is a rather small current of electricity (approximately what a 100-watt light bulb would draw), it is actually a tremendous flow of electrons. More than 6 billion billion electrons a second are required to make up one ampere.

b. Voltage. Electrons are caused to flow by a difference in electron balance in a circuit; that is, when there are more electrons in one part of a circuit than in another, the electrons move from the area where they are concentrated to the area where they are lacking. This difference in electron concentration is called potential difference, or voltage. The higher the voltage goes, the greater the electron imbalance becomes. The greater this electron imbalance, the harder the push on the electrons (more electrons repelling each other) and the greater the current of electrons in the circuit. When there are many electrons concentrated at the negative terminal of a generator (with a corresponding lack of electrons at the positive terminal), there is a much stronger repelling force on the electrons and, consequently, many more electrons moving in the wire. This is exactly the same as saying that the higher the voltage, the more electric current will flow in a circuit, all other things, such as resistance (para 11-10), being equal.

11-10. Resistance.

a. Even though a copper wire will conduct electricity with relative ease, it still offers resistance to electron flow. This resistance is caused by the energy necessary to break the outer shell electrons free, and the collisions between the atoms of the conductor and the free electrons. It takes force (or voltage) to overcome the resistance encountered by the flowing electrons. This resistance is expressed in units called ohms. The resistance of a conductor varies with its length, cross-sectional area, composition, and temperature.

b. A long wire offers more resistance than a short wire of the same cross-sectional area. The electrons have farther to travel.

c. Some elements can lose electrons more readily than other elements. Copper loses electrons easily, so there are always many free electrons in a copper wire. Other elements, such as iron, do not lose their electrons quite as easily, so there are fewer free electons in an iron wire (comparing it to a copper wire of the same size). Thus, with fewer free electrons, fewer electrons can push through an iron wire; that is, the iron wire has more resistance than the copper wire.

d. A small wire (in thickness or cross-sectional area) offers more resistance than a large wire. In the small wire, there are fewer free electrons (because fewer atoms), and thus fewer electrons can push through.

e. Most metals show an increase in resistance with an increase in temperature, while most nonmetals show a decrease in resistance with an increase in temperature. For example, glass (a nonmetal) is an excellent insulator at room temperature but is a very poor insulator when heated to red heat.

11-11. Ohm's Law.

a. The general statements about voltage, amperage, and ohms (para 11-9 and 11-10) can all be related in a statement known as ohm's law, so named for the scientist Georg Simon Ohm who first stated the relationship. This law says that voltage is equal to amperage times ohms. Or, it can be stated as the mathematical formula:

$$E = I \times R$$

where E is volts, I is current in amperes, and R is resistance in ohms. For the purpose of solving problems, the ohms law formula can be expressed three ways:

(1) To find voltage: $E = IR$

(2) To find amperage: $I = E/R$

(3) To find ohms: $R = E/I$

b. This formula is a valuable one to remember because it makes understandable many of the things that happen in an electric circuit. For instance, if the voltage remains constant, the

244

current flow goes down if the resistance goes up. An example of this would be the lighting circuit that is going bad in a truck. Suppose the wiring circuit between the battery and the lights has deteriorated due to connections becoming poor, strands in the wire breaking, switch contacts becoming dirty, or other, similar problems. All of these conditions reduce the electron path or, in other words, increase resistance. And, with this increased resistance, less current will flow. The voltage of the battery stays the same (for example, 12 volts). If the resistance of the circuit when new (including light bulbs) was 6 ohms, then 2 amperes will flow. To satisfy the equation, 12 (volts) must equal 12 (amperes times ohms resistance). But if the resistance goes up to 8 ohms, only 1.5 amperes can flow. The increased resistance cuts down the current flow and, consequently, the amount of light.

c. A great majority of electrical troubles on automotive vehicles result from increased resistance in circuits due to bad connections, deteriorated wiring, dirty or burned contacts in switches, or other such problems. With any of these conditions, the resistance of the circuit goes up and the ampere flow through that circuit goes down. Bad contact points in the ignition circuit will reduce current flow in the circuit and cause weak sparks at the spark plugs. This will result in engine missing and loss of power.

d. If the resistance stays the same but the voltage increases, the amperage also increases. This is a condition that might occur if a generator voltage regulator became defective. In such a case, there would be nothing to hold the generator voltage within limits, and the voltage might increase excessively. This would force excessive amounts of current through various circuits and cause serious damage. If too much current went through the lightbulb filaments, for example, the filaments would overheat and burn out. Also, other electrical devices probably would be damaged.

e. On the other hand, if the voltage is reduced, the amount of current flowing in a circuit will also be reduced if the resistance stays the same. For example, with a run-down battery, battery voltage will drop excessively with a heavy discharge. When trying to start an engine with a run-down battery, the voltage will drop very low. This voltage is so low that it cannot push enough current through the starter for effective starting of the engine.

11-12. Circuit Configurations.

a. General (Fig. 11-12). A very basic circuit consists of a power source, a unit to be operated, and a wire to connect the two together. If the unit to be operated is to be controlled, a switch will be included in the circuit also.

b. Automotive Circuits (Fig. 11-13). The body and chassis in an automobile are made of steel. This feature is utilized to eliminate one of the wires from all of the automobile's circuits. By attaching one of the battery terminals to the body and chassis, any electrical component can be connected by hooking up one side, by wire, to the car battery and the other side to the body. The practice of connecting one side of the battery to the automobile body is called grounding. Virtually all current automotive manufacturers ground the negative side of the battery. This is referred to as an electrical system with a negative ground. Vehicles with a positive ground are very uncommon at the present time.

c. Series Circuits (A, Fig. 11-14). A series circuit consists of two or more resistance units (electrically operated components) that are connected together in an end-to-end manner so that any current flow in the circuit is dependent on a complete path through all of the units. The following characteristics of series circuits are important:

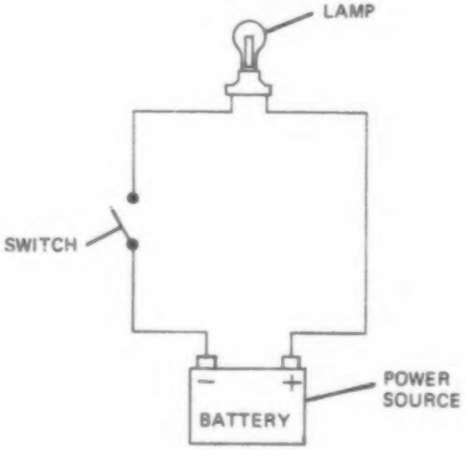
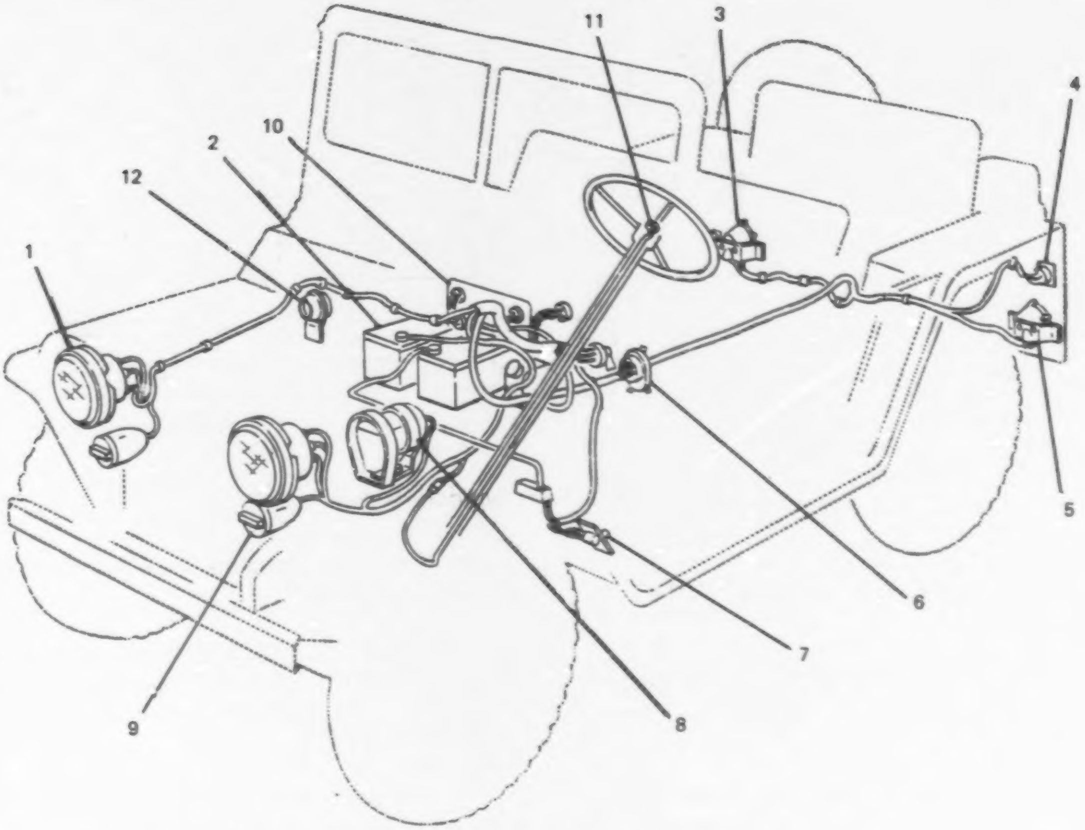


Figure 11-12. Basic Electrical Circuit.

TA233528

245

BEST COPY AVAILABLE



1. HEADLIGHT
2. BATTERIES
3. BLACKOUT AND SERVICE TAILLIGHT
4. TRAILER RECEPTACLE
5. BLACKOUT TAILLIGHT, SERVICE TAILLIGHT, AND SERVICE STOPLIGHT
6. LIGHT SWITCH
7. DIMMER SWITCH
8. BLACKOUT DRIVE LIGHT
9. BLACKOUT SERVICE LIGHT
10. INSTRUMENT CLUSTER
11. HORN BUTTON
12. HORN

Figure 11-13. Typical Automotive Circuit.

(1) Any break in the circuit (such as a burned-out light bulb) will render the entire circuit inoperative.

(2) The current (amperage) will be constant throughout the circuit.

(3) The total resistance of the circuit is equal to the sum of the individual resistances.

(4) The total voltage of the circuit is equal to the sum of the individual voltage drops across each component.

d. Parallel Circuits (B, Fig. 11-14). A parallel circuit consists of two or more resistance units (electrically operated components) connected in separate branches. In a parallel circuit, each component receives full voltage from the source. The following characteristics of parallel circuits are important.

(1) The total resistance of the circuit will always be less than the resistance of any individual component.

(2) The disconnection or burning out of any individual component in the circuit will not affect the operation of the others.

(3) The current will divide itself among the circuit branches according to the resistances of

TA233529

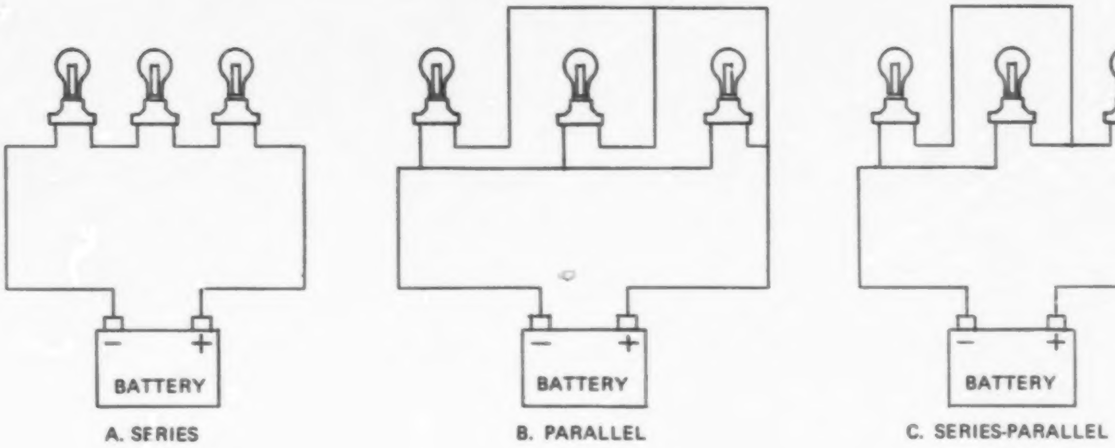


Figure 11-14. Circuit Configurations.

the individual components. The sum of the individual amperages will be equal to the total circuit current.

(4) The voltage will be constant throughout the circuit when measured across the individual branches.

e. Series-Parallel Circuit (C, Fig. 11-14). The series-parallel circuit is a combination of the two configurations. There must be at least three resistance units to have a series-parallel circuit. The following characteristics of series-parallel circuits are important.

(1) The total circuit voltage will be equal to the sum of the total parallel circuit voltage drop plus the voltage drops of the individual series circuit components.

(2) The total circuit resistance will be equal to the sum of the total parallel circuit resistance plus the individual resistances of the series circuit components.

(3) Current flow through the total parallel circuit will be equal to the current flow through any individual series circuit component.

(4) The disconnection or the burning out of any of the series components will completely disable the entire circuit, whereas a failure of any of the parallel circuit components will leave the balance of the circuit still functioning.

Section IV. MAGNETS

11-13. Magnetic Field.

a. General. It was stated in paragraph 11-9 that electric current is a flow of electrons and that the imbalance of electrons in a circuit (that causes electrons to flow) is called voltage. Magnets will be studied to learn what causes a generator to concentrate electrons at the negative terminal and take them away from the positive terminal.

b. Magnetic Lines of Force. If iron filings were sprinkled on a piece of glass on top of a bar magnet, the filings would become arranged in curved lines (fig. 11-15). These curved lines, extending from the two poles of the magnet (north and south), follow the magnetic lines of force surrounding the magnet. Scientists have formulated the following rules for these lines of force.

(1) The lines of force (outside the magnet) pass from the north to the south pole of the magnet.

(2) The lines of force act somewhat as rubberbands and try to shorten to a minimum length.

TA233530

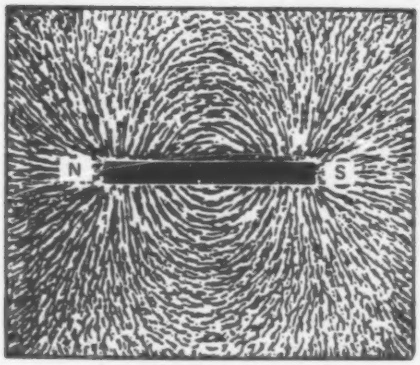


Figure 11-15. Magnetic Lines of Force.

(3) The lines of force repel each other along their entire length and try to push each other apart.

(4) The rubberband characteristic opposes the push-apart characteristic.

(5) The lines of force never cross each other.

(6) The magnetic lines of force, taken together, are referred to as the magnetic field of the magnet.

c. Bar and Horseshoe Magnets. The magnetic fields of a bar and of a horseshoe magnet are shown in figure 11-16. In each, note how the lines of force curve and pass from the north to the south pole.

d. Effects Between Magnetic Poles (Fig. 11-17). When two unlike magnetic poles are brought together, they attract. But when like magnetic poles are brought together, they repel. These actions can be explained in terms of the rubberband and the push-apart characteristics. When unlike poles are brought close to each other, the magnetic lines of force pass from the north to the south poles. They try to shorten (like rubberbands), and, therefore, try to pull the two poles together. On the other hand, if like poles are brought close to each other, lines of force going in the same direction are brought near each other. Because these lines of force attempt to push apart, a repelling effect results between the like poles.

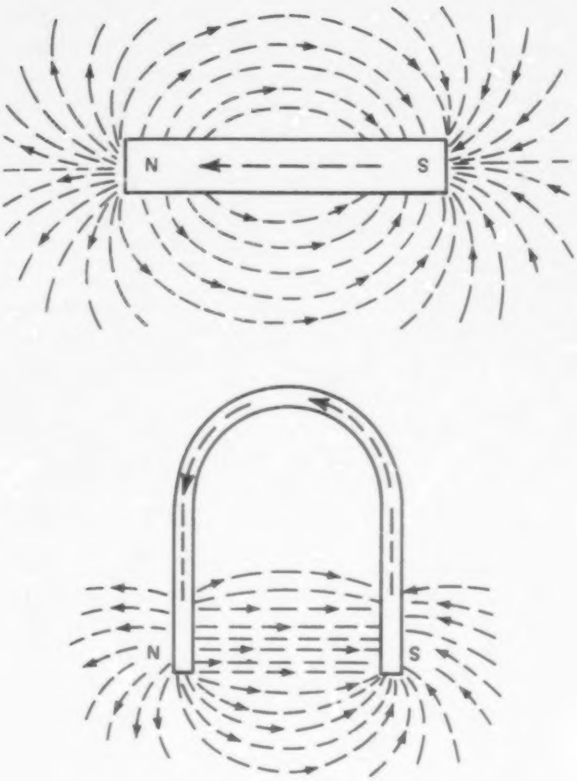


Figure 11-16. Bar and Horseshoe Magnet.

11-14. Electromagnetism.

a. An electric current (flow of electrons) always produces a magnetic field. In the wire

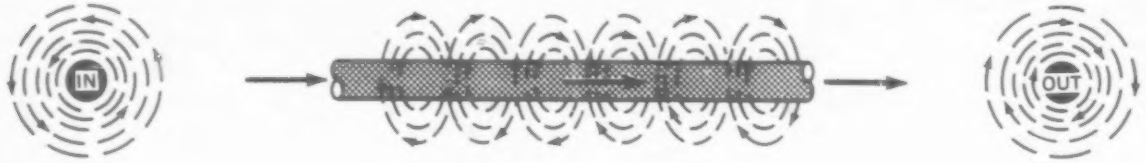


Figure 11-17. Effects Between Magnetic Poles.

TA233531

shown in figure 11-18, current flow causes lines of force to circle the wire. It is thought that these lines of force result from the movement of the electrons along the wire. As they move, the electrons send out the lines of force. When many electrons move, there are many lines of force (the magnetic field is strong). Few electrons in motion means a weak magnetic field or few lines of force.

b. Electron movement as the basis of magnetism in bar and horseshoe magnets can be explained by assuming that the atoms of iron are so lined up in the magnets that the electrons are circling in the same direction. With the electrons moving in the same direction, their individual magnetic lines of force add to produce the magnetic field.

c. The magnetic field produced by current flowing in a single loop of wire is shown in figure 11-19. The magnetic lines of force circle the wire, but here they must follow the curve of the wire. If two loops are made in the conductor, the lines of force will circle the two loops. In the area between the adjacent loops, the magnetic lines are going in opposite directions. In such a case, because they are of the same strength (from same amount of current traveling in both loops), they cancel each other out. The lines of force, therefore, circle the two loops almost as though they were a single loop. However, the magnetic field will be twice as strong because the lines of force of the two loops combine.

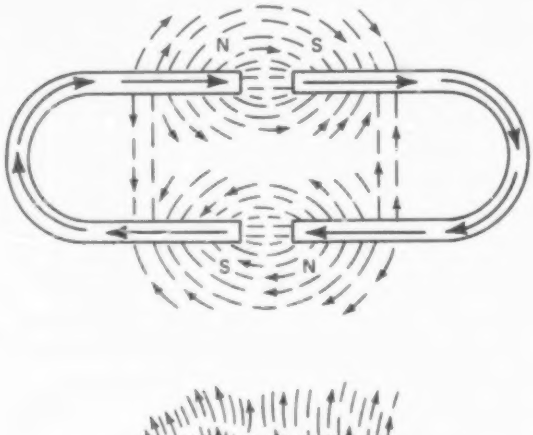


Figure 11-18. Electromagnetism.

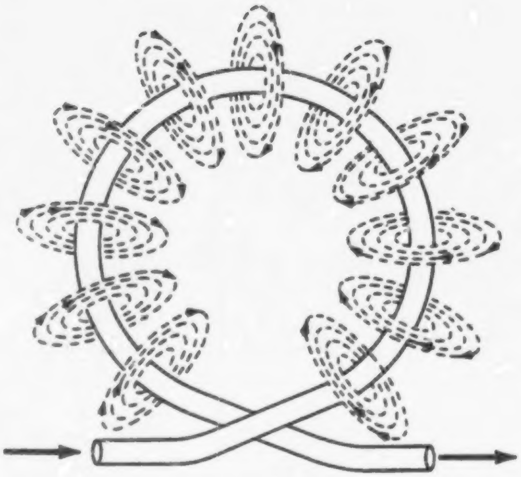


Figure 11-19. Electromagnetism in a Wire Loop.

d. When many loops of wire are formed into a coil as shown in figure 11-20, the lines of force of all loops combine into a pattern that resembles greatly the magnetic field surrounding a bar magnet. A coil of this type is known as an electromagnet or a solenoid. However, electromagnets can be in many shapes. The field coils of generators and starters, the primary winding in an ignition coil, the coils in electric gages, even the windings in a starter armature, can be considered to be electromagnets. All of these produce magnetism by electrical means, as discussed in paragraph 11-15.

e. The north pole of an electromagnet can be determined, if the direction of current flow (from negative to positive) is known, by use of the left-handed rule (fig. 11-21). The left hand is held around the coil with the fingers pointing in the direction of current flow. The thumb will point to the north pole of the electromagnet. This rule is based on current, or electron, flow from negative to positive.

TA233532

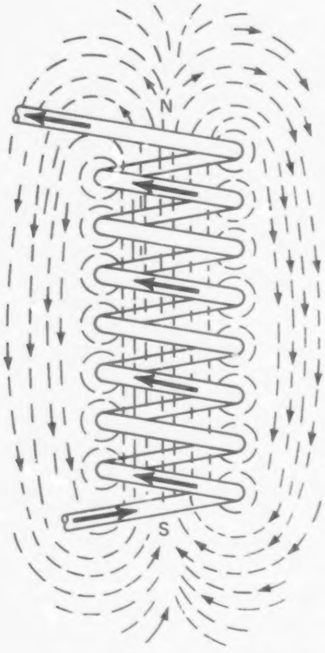


Figure 11-20. Electromagnetism in a Wire Coil.

f. The left-handed rule also can be used to determine the direction that lines of force circle a wire-carrying current if the direction of current is known. This is done by circling the wire with the left hand with the thumb pointing in the direction of current flow (negative to positive). The fingers will then point in the direction that the magnetic field circles the wire.

g. The strength of an electromagnet can be increased greatly by wrapping the loops of wire around an iron core. The iron core passes the lines of force with much greater ease than air.

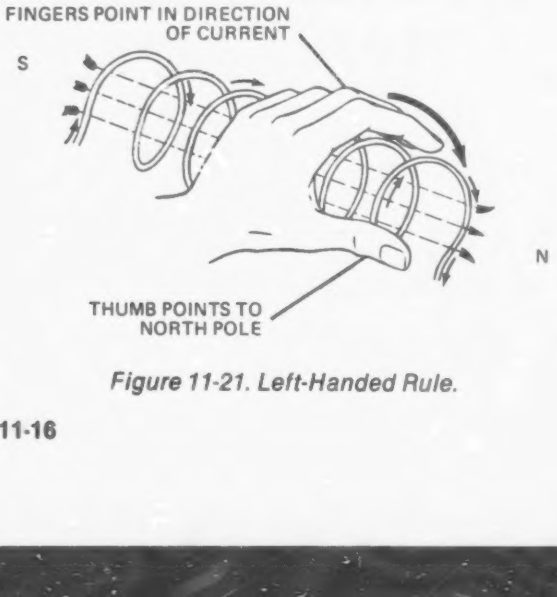

FINGERS POINT IN DIRECTION OF CURRENT
S
N
THUMB POINTS TO NORTH POLE

Figure 11-21. Left-Handed Rule.

This effect of permitting lines of force to pass through easily is called permeability. Wrought iron is 3,000 times more permeable than air. In other words, it allows 3,000 times as many lines of force to get through. With this great increase in the number of lines of force, the magnetic strength of the electromagnet is increased greatly, even though no more current flows through it. Practically all electromagnets use an iron core of some kind.

11-15. Electromagnetic Induction.

a. Current can be induced to flow in a conductor if it is moved through a magnetic field. In figure 11-22 the wire is moved downward through the magnetic field between the two magnetic poles. As it moves downward, cutting lines of force, current is induced in it. The reason for this is that the lines of force resist cutting, and tend to wrap around the wire as shown. With lines of force wrapping around the wire, current is induced. The wire movement through the magnetic field produces a magnetic whirl around the wire, which pushes the electrons along the wire.

b. If the wire is held stationary and the magnetic field is moved, the effect is the same; that is, current will be induced in the wire. All that is required is that there be relative movement between the two so that lines of force are cut by the wire. It is this cutting and whirling, or wrapping, of the lines of force around the wire that produces the current movement in the wire.

c. The magnetic field can be moved by moving the magnet or, if it is a magnetic field from an electromagnet, it can be moved by starting and stopping the current flow in the electromagnet. Suppose an electromagnet such as the one shown in figure 11-20 has a wire held close to it. When the electromagnet is connected to a battery, current will start to flow through it. This current, as it starts to flow, builds up a magnetic field. In other words, a magnetic field forms because of the current flow. This magnetic field might be considered as expanding (like a balloon, in a sense) and moving out from the electromagnet. As it moves outward, its lines of force will cut through the wire held close to the electromagnet. This wire, therefore, will have current induced in it. The current will result from the lines of force cutting across the wire. If the electromagnet is

TA233533

250

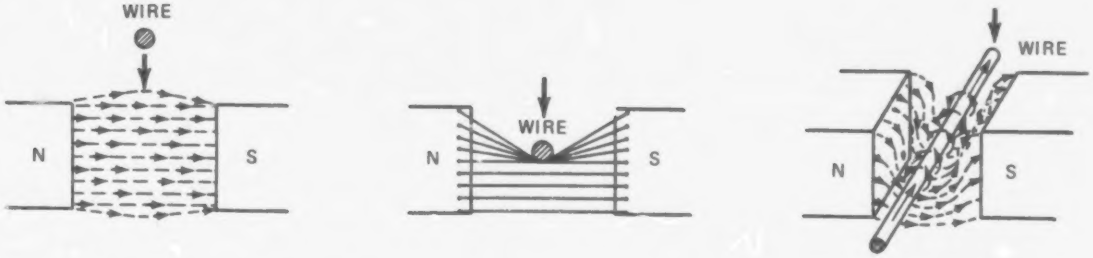


Figure 11-22. Electromagnetic Induction.

disconnected from the battery, its magnetic field will collapse and disappear. As this happens, the lines of force move inward toward the electromagnet. Again, the wire held close to the electromagnet will be cut by moving lines of force and will have a current induced in it. This time, the lines of force are moving in the opposite direction and the wire, therefore, will have current induced in it in the opposite direction.

d. Thus it can be seen that current can be induced in the wire by three methods: the wire can be moved through the stationary magnetic field; the wire can be held stationary and the magnet can be moved so the field is carried past the wire; or the wire and electromagnet both can be held stationary and the current turned on and off to cause the magnetic field buildup and collapse, so the magnetic field moves one way or the other across the wire.

TA233534

251

BEST COPY AVAILABLE

CHAPTER 12

BATTERIES

Section I. CONSTRUCTION

12-1. General. The storage battery provides electrical energy through chemical reactions. When a generator in the electrical system of a motor vehicle produces more electrical energy than required for ignition and for operating electrical accessories, the surplus (under certain conditions) passes through the battery to reverse the chemical reaction. This is known as charging the battery. When the generator is not producing the necessary electrical energy, the battery, through chemical reaction, can supply the energy required in the electrical system of the vehicle. The battery then is said to be discharging. The most common battery for automotive use is the lead-acid battery.

12-2. Component Parts. The storage battery, as used for starting, lighting, and ignition purposes, consists of three or more cells, depending on the voltage desired. A battery of three cells (2 volts each) connected in series is a 6-volt battery, and one of six cells connected in series is a 12-volt battery. Typical battery construction is shown in figure 12-1.

a. Plates.

(1) Each cell consists of a hard rubber jar or compartment into which two kinds of lead plates, known as positive and negative, are placed. These plates are insulated from each other by suitable separators and are submerged in a sulfuric acid solution.

(2) The backbone of both the positive and negative plates is a grid made of stiff lead alloy casting. The grid, usually composed of vertical and horizontal crossmembers, is designed carefully to give the plates mechanical strength and, at the same time, to provide adequate conductivity for the electric current created by the chemical action. The active material, composed chiefly of

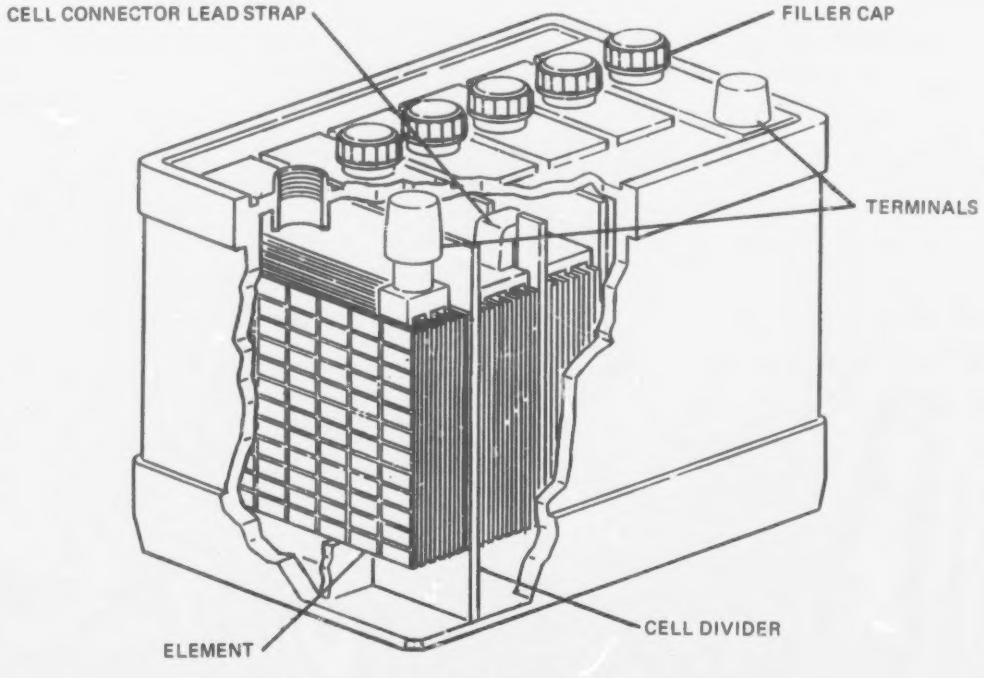


Figure 12-1. Cross Section of a Typical Storage Battery.

TA233536

lead oxides, is applied to the grids in paste form, then allowed to dry and harden like cement. Part of a grid is shown in figure 12-2 with a cross section showing the active material in place. The plates are then put through an electrochemical process that converts the hardened active material of the positive plates into brown lead peroxide, and that of the negative plates into gray, spongy, metallic lead. This process is known as forming the plates.

b. Groups. After the plates have been formed, they are built into positive and negative groups. The plates of each group are permanently joined by melting a portion of the lug on each plate to form a solid weld with a connecting post strap. The heat necessary for this process, termed lead burning, is produced by a gas flame or an electric arc. The connecting post strap to which the plate lugs are burned contains a cylindrical terminal that forms the outside connection for the cell. The negative group of plates has one more plate than the positive group to provide a negative plate on both sides of all positive plates. These groups are shown in figure 12-3.

c. Separators. To prevent the plates from touching and causing a short circuit, sheets of insulating material (microporous rubber, fibrous glass, or plastic-impregnated material), called separators, are inserted between the plates. These separators (fig. 12-4) are thin and porous so the electrolyte will flow easily between the plates. One side of the separator (that is placed against the positive plate) is grooved so the gas that forms during charging will rise to the surface more readily. These grooves also provide room for any material that flakes from the plates to drop to the sediment space below.

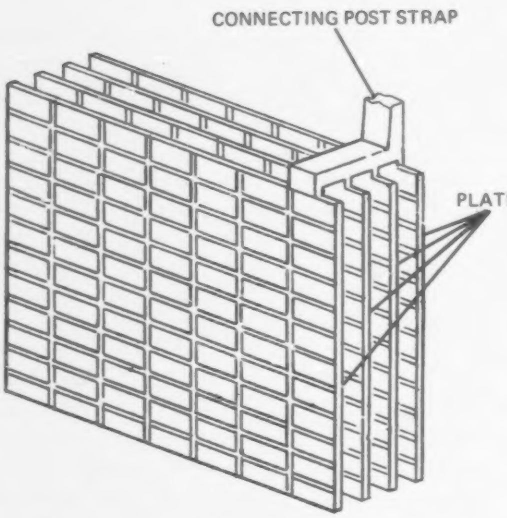


Figure 12-3. Cell Group Construction.

d. Elements. The assembly of a positive and negative group, together with the separators, is called an element (fig. 12-4). Because storage battery plates are more or less of standard size, the number of plates in an element is, roughly, a measure of the battery capacity. The distance between the plates of an assembled element is approximately one-eighth inch.

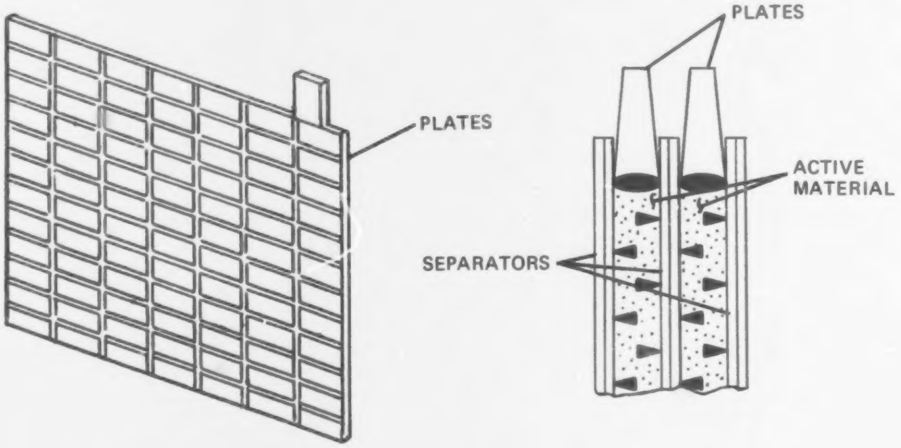


Figure 12-2. Plate Construction.

TA233536

253

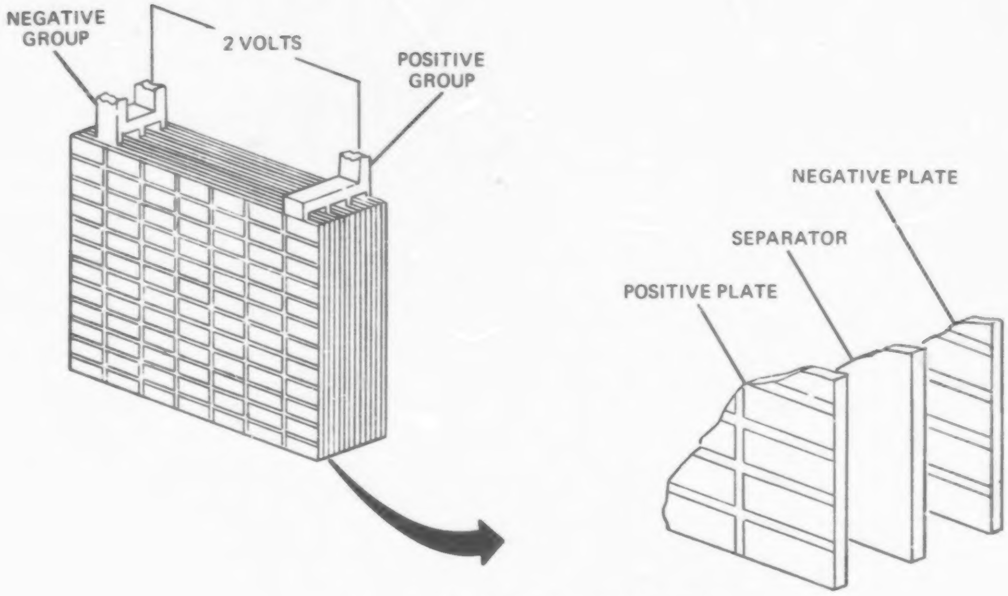


Figure 12-4. Battery Cell Elements.

e. Electrolyte.

(1) *Composition.* An electrolyte is a liquid that conducts electricity readily and is decomposed when an electric current passes through it. The electrolyte in the lead-acid storage battery has a specific gravity of 1.28, which means that it is 1.28 times as heavy as water. It is composed of one part of chemically pure sulfuric acid and approximately two and three-fourths parts, by volume, of distilled water. A small quantity of some impurity introduced into the acid solution by using impure water might interfere with the chemical action and cause battery trouble.

(2) *Specific Gravity Readings.* Specific gravity is the ratio of the weight of the same volume of chemically pure water at 39°F (4°C). The specific gravity of sulfuric acid is 1.835; that is, sulfuric acid is 1.835 times heavier than water. The electrolyte of a storage battery is a mixture of water and sulfuric acid. The amount of sulfuric acid in the electrolyte changes with the amount of electrical charge; also, the specific gravity of the electrolyte changes with the amount of electrical charge. This provides a convenient way of measuring the degree of charge in a battery. A fully charged battery will have a specific gravity of 1.28 at 80°F (26.6°C). The figure will go higher with a temperature decrease and lower with a temperature increase.

(3) *Tropical Operation.*

(a) When batteries are operated in tropical climates, the full-charge specific gravity should be reduced to a value between 1.2 and 1.225 by dilution with water. Rainwater may be used if distilled water is not available.

(b) At the high temperatures encountered in the tropics, the acid in the electrolyte is more active and a weaker concentration will give satisfactory results with less damage to plates and separators.

(c) When the electrolyte is diluted, a special tag, giving the full-charge specific gravity, will be attached to the battery and also a 1-inch white spot will be painted on the battery top. If the battery is a nonmilitary type, it may have exposed cell connector straps and these will be painted white. Be careful to readjust the specific gravity before shipping such batteries to frigid areas.

f. Container.

(1) A battery container is a receptacle for the cells that make up the battery. It is made of hard rubber or a polypropylene plastic, which is resistant to acid and mechanical shock. Most motor vehicle batteries are assembled in one-piece containers (fig. 12-5) with three or six

TA233537

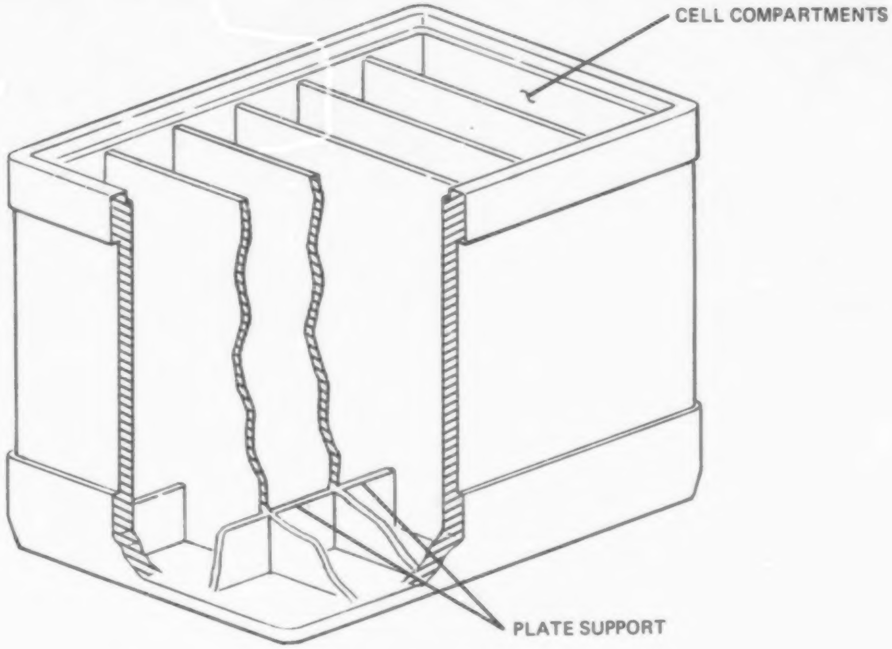


Figure 12-5. Battery Container Construction.

compartments for the individual cells. One element and enough electrolyte to cover the plates are inserted into each cell compartment.

(2) Stiff ridges, or ribs, molded in the bottom of the container form a support for the plates and a sediment recess for the flakes of active material that drop off the plates during the life of the battery. The sediment is thus kept clear of the plates so it will not cause a short circuit across them.

g. Cover. After all of the elements have been fitted into the case, they are connected together in series by burning lead cell connectors across the terminals. The battery top then is sealed with a hard rubber cover that provides openings for the two battery posts and a vent plug for each cell. The vent plugs allow gas to escape and prevent the electrolyte from splashing outside the battery. The battery is filled through the vent plug openings.

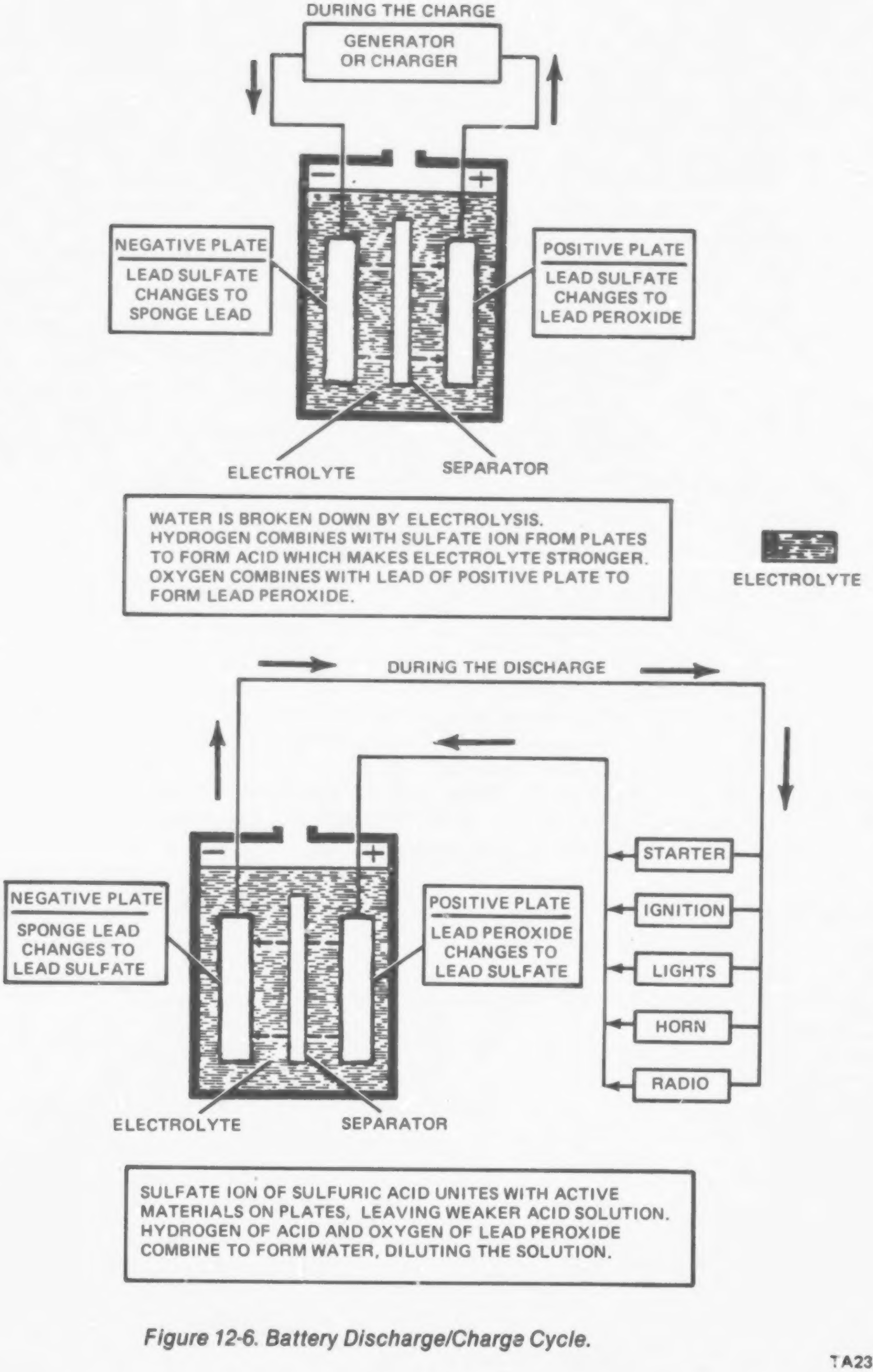
Section II. PRINCIPLES OF OPERATION

12-3. General. When a cell is fully charged, the negative plate is spongy lead, the positive plate is lead peroxide, and the electrolyte contains a maximum amount of sulfuric acid. Both the negative and positive plates are very porous and are acted upon readily by the acid. A cell in this condition can produce electrical energy through reaction of the chemicals.

12-4. Discharge. If the terminals of the battery are connected to a closed circuit, the cell discharges to supply electric current (fig. 12-6). The chemical process that occurs during discharge changes both the lead of the negative plate and the lead peroxide of the positive plate to lead sulfate and the sulfuric acid to water. Thus, the electrolyte becomes weaker during discharge, because the water increases and the sulfuric acid decreases. As the discharge continues, the negative and the positive plates finally contain considerable lead sulfate and the electrolyte turns to almost pure water. At this point the battery will stop providing current flow.

12-5. Charge.

a. Chemical Action. To charge the cell, an external source of direct current must be connected to the battery terminals. The chemical reaction is reversed then and returns the positive


DURING THE CHARGE
GENERATOR OR CHARGER
NEGATIVE PLATE
LEAD SULFATE CHANGES TO SPONGE LEAD
POSITIVE PLATE
LEAD SULFATE CHANGES TO LEAD PEROXIDE
ELECTROLYTE
SEPARATOR
ELECTROLYTE
DURING THE DISCHARGE
NEGATIVE PLATE
SPONGE LEAD CHANGES TO LEAD SULFATE
POSITIVE PLATE
LEAD PEROXIDE CHANGES TO LEAD SULFATE
STARTER
IGNITION
LIGHTS
HORN
RADIO
ELECTROLYTE
SEPARATOR

WATER IS BROKEN DOWN BY ELECTROLYSIS. HYDROGEN COMBINES WITH SULFATE ION FROM PLATES TO FORM ACID WHICH MAKES ELECTROLYTE STRONGER. OXYGEN COMBINES WITH LEAD OF POSITIVE PLATE TO FORM LEAD PEROXIDE.

SULFATE ION OF SULFURIC ACID UNITES WITH ACTIVE MATERIALS ON PLATES, LEAVING WEAKER ACID SOLUTION. HYDROGEN OF ACID AND OXYGEN OF LEAD PEROXIDE COMBINE TO FORM WATER, DILUTING THE SOLUTION.

Figure 12-6. Battery Discharge/Charge Cycle.

TA233539

256

and negative plates and the electrolyte to their original condition. When all the sulfate on the plates has been returned to the electrolyte to form sulfuric acid, the cell is recharged fully and ready to be used for the next discharge. Charging should be started before both plates have become sulfated entirely. The chemical process in the cell during discharge and charge is shown in figure 12-6.

b. *Electrical Action.* A storage battery can be charged by direct current only. If only alternating current is available, a motor-generator set or a rectifier must be used to convert it into direct current. In charging, the positive wire of the charging circuit must always be connected to the positive (+) terminal of the battery and the negative wire to the negative (-) terminal. The electrolyte in each cell must be brought to the proper level by the addition of pure water before the battery is charged.

c. *Capacity.* All batteries are given normal capacity ratings according to the ampere-hours obtained from the battery under certain working conditions. The capacity of a battery is the number of amperes delivered, multiplied by the number of hours the battery is capable of delivering this current. One of the inherent characteristics of a storage battery is that its ampere-hour capacity depends upon the rate of discharge. A battery will give more ampere-hours at a long, low, or intermittent discharge rate than at a short, high, or continuous discharge rate. This is because the voltage drops faster at higher rates. Like other chemical processes, the battery is less efficient in cold weather than in hot weather. At 0°F (-18°C), a battery has only approximately 40 percent of the full cranking capacity available at 80°F (27°C). In an emergency, little, if any, permanent harm will result if the battery is discharged at a very high rate, provided it is promptly recharged. The battery is likely to deteriorate if left in a discharged condition.

Section III. TYPES OF BATTERIES

12-6. Deep-Cycle Battery. Deep-cycle batteries are units that are designed to be subjected to heavy discharge loads for long periods of time. They also must be able to take high-rate charging. The batteries used in forklifts (or any electric vehicles) are nickel cadmium or lead acid. Because the initial cost of nickel-cadmium batteries are approximately 35 times that of lead acid, they are used only when their cost can be justified in terms of their extremely long cycle life. Lead-acid batteries come in four basic varieties:

a. *SLI Battery.* The SLI (starting, lighting, and ignition) battery is designed to deliver high power outputs for relatively short periods of time. Because of its thin plate design, it has less energy available than a deep cycle battery and will have a life limited to less than 100 deep discharge cycles. It is suited to automotive usage because it is lightweight and has a higher specific power output (power-per-pound) than deep cycle batteries. In normal automotive usage, the life of an SLI battery may exceed 5,000 shallow cycles (starting an engine and recharging would be considered a shallow cycle).

b. *Golf Cart Battery.* The golf cart battery must be able to sustain high discharge rates for relatively long periods of time. At the same time, they must have a high specific power output and be relatively lightweight. The golf cart battery has thicker plates than the SLI battery and can withstand about 200 to 400 deep cycles.

c. *Semi-Industrial Battery.* The semi-industrial battery has thicker plates and is larger and heavier than the golf cart battery. It can withstand about 500 to 1,000 deep cycles through its life.

d. *Industrial Battery.* The industrial battery is used mainly as a source of power in electric industrial vehicles, where cycle life and total power output are important. In some cases industrial batteries will use tubular plates instead of the standard pasted plates. This design can withstand as much as 2,000 deep cycles during its life though it exhibits a low power density, resulting in a very large, heavy battery.

12-7. Nickel-Cadmium Batteries.

a. *General.* The nickel-cadmium, alkaline battery has been receiving serious consideration

257

and extensive testing for tank-automotive applications. This battery employs nickel and cadmium compounds as the active material and potassium hydroxide as electrolyte. There are actually two basic types of nickel-cadmium batteries. These are distinguished by the method used to construct the plates. One is called a pocket plate and the other a sintered-plate design. In addition, the nickel-cadmium battery is produced with both vented cells and completely sealed cells. The vented sintered-plate, nickel-cadmium battery is the one most often used in military applications because it offers high discharge rates at wider temperature ranges. For this reason, the discussion of the nickel-cadmium battery will be confined largely to the sintered-plate version. The basic difference between the pocket and sintered plate is that, in the pocket type, the active material of the plates is encased within perforated steel pockets, while the sintered type has the active material contained in a sintered structure surrounding the grid. Although the sintered method is more expensive per ampere-hour than the pocket plate type, superior performance at high rates and reduced capacity loss at low temperatures qualify it as the logical choice for military applications.

b. Construction.

(1) The sintered plate consists of three components. One is the metal grid that acts as the current collector. This grid is constructed either of pure nickel, a woven screen of nickel-plated steel, expanded metal, or perforated sheet. The second component is a fine nickel powder that is sintered on the grid and has a porosity of approximately 80 percent. The third component is the active material that is impregnated in the pores of the sintered powder. A nickel salt is used for the active material in the positive plate, and a cadmium salt for the negative.

(2) Once the plates are constructed, they are formed into cell elements similar to the lead-acid battery. The plates are isolated from one another with nylon-cellophane type separators and placed into a container usually of high-impact plastic.

(3) The positive plate of the nickel-cadmium battery is made up of $Ni(OH)_3$ and $Ni(OH)_2$ whereas the negative consists of Cd and $Cd(OH)_2$. During discharge, the trivalent nickel hydroxide $Ni(OH)_3$ is converted to the divalent hydroxide $Ni(OH)_2$ at the positive plate with the reverse process occurring during charging. The negative plate consists of metallic cadmium when fully charged. This is converted to the hydroxide during discharge and back to metallic cadmium during charging.

c. Features.

(1) The low internal resistance of the sintered-plate battery makes it ideal for service requiring long battery life and high current drains over a wide temperature range.

(2) The sintered-plate construction of the positive and negative electrode allows plates to be constructed as thin as 0.02 inch. This allows more plates to be installed in a given size cell with less space between plates. The internal resistance of the sintered-plate cell is thus about one-half that of a pocket plate type.

(3) The specific gravity of the potassium hydroxide electrolyte does not change during charge or discharge. This is because the electrolyte does not enter into the chemical reaction between the positive and negative electrodes, as does sulfuric acid in the lead acid battery. For this reason, specific gravity readings of the nickel-cadmium electrolyte are not an indication of the state-of-charge. The open circuit voltage of a charged nickel-cadmium cell is about 1.3 volts, and the average and final discharge voltages at normal rates of discharge are about 1.2 and 1.1 volts, respectively.

(4) The fact that the electrolyte serves virtually as a conductor offers several advantages. One is that very little gassing occurs on charging, except when overcharged, and none on discharge. Therefore, little water is lost. Another is that the rate of self-discharge is very low. Thus, the battery may be left standing on open circuit for periods up to a year and still retain as much as 70 percent of its original charge. Still another advantage of the nickel-cadmium battery is that it will accept a charge at a temperature as low as −40°F, by virtue of self-heating. At temperatures below −40°F, however, the electrolyte forms a slush that does slow down chemical reactions.

(5) The last two characteristics in table 12-1 point out possibly the most and least desirable features of the nickel-cadmium battery; that is, the desirable feature of cranking ability at low temperature, and the undesirable initial acquisition cost. The latter indicates an initial cost of approximately 35 times that of the lead-acid battery. Whether this added cost can be justified by longer life and better performance is up to the electrical designer to evaluate in that particular application. In addition, the manufacture of nickel-cadmium batteries requires critical materials during war time.

d. Performance Characteristics. A discharge performance comparison between the nickel-cadmium battery and the lead-acid battery is shown in figure 12-7. This figure shows discharge characteristics of fully charged 34 ampere-hour, 24-volt, lead-acid and nickel-cadmium batteries discharged at the 1-hour rate of 30 amperes. This figure illustrates an important characteristic of the nickel-cadmium battery, that is, its ability to maintain a nearly constant voltage until approximately 90 percent of the capacity is delivered. This feature, combined with its recharge capability at low temperatures, makes the nickel-cadmium battery a prime candidate for heavy-duty applications.

12-8. Maintenance-Free Battery.

a. General. Another development that could be applied to military vehicles is the maintenance-free battery now used for commercial application. This battery is a completely sealed unit that requires no maintenance. The major difference between this battery and conventional design is the absence of antimony in the lead grids.

b. Features. Because lead alone is not rigid enough to hold its form in use, antimony usually is added to stiffen conventional battery plates. As a result of the added antimony, the conventional battery uses an excessive amount of water during the charge and discharge cycles. In the maintenance-free battery, the designers replaced the antimony with a calcium additive to strengthen the plates. This design effort resulted in a battery with very little water loss over its lifetime. Another advantage of the sealed battery is that the battery posts do not become corroded as a result of acid leakage. However, batteries filled and sealed at the factory would become a charging problem in the military system due to wet storage. Because of shipping delay and distances involved, and long-term storage requirements, a battery seldom is used within the first year after its production.

12-9. Other Storage Batteries.

a. General. Although the lead-acid and the nickel-cadmium storage batteries have received the most attention, several other battery types deserve a brief description. These are: nickel iron, nickel zinc, silver zinc, and silver cadmium.

Table 12-1. Lead-Acid Vs Nickel-Cadmium Batteries.

	Lead Acid	Nickel Cadmium
Battery weight, lb	70	70
Number of cells	6	10
Voltage	12	12
A-hr capacity (5-A rate)	100	70
Cranking ability at – 40°F, minimum time, at 300-A rate	1.25	5.5
Initial acquisition cost (current Government catalog)	$25	$1000

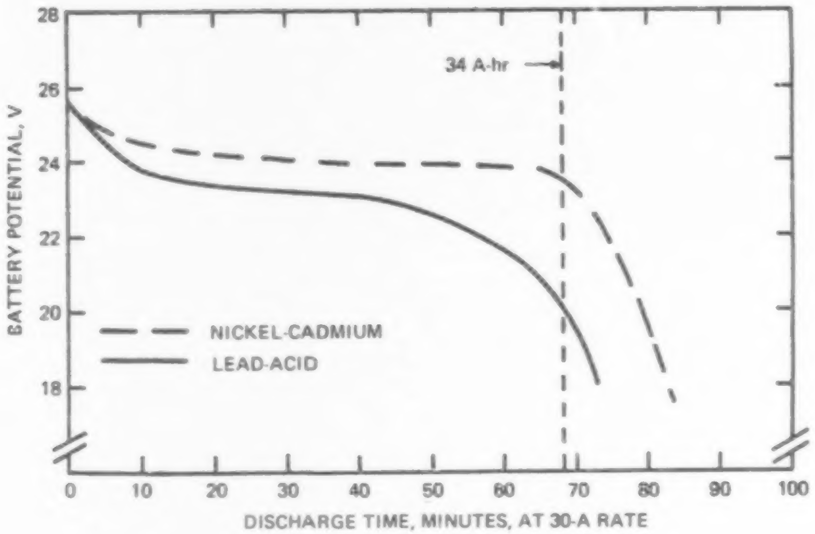


Figure 12-7. Comparison of Discharge Characteristics.

b. Nickel Iron. This is a battery of rugged construction, used for many years for heavy cycling service to provide reliable, long-life service in applications such as electric industrial trucks and railway cars. The battery may have limited use in certain tank-automotive applications. Charging problems occur due to high overvoltage and performance is poor at low temperatures.

c. Nickel Zinc. This battery has received attention only in recent years. It is still in the development stage. Problems to be overcome are low nickel plate capacity, separator deterioration, and poor zinc cycle life. With added improvements it could become competitive with silver-zinc types in many applications.

d. Silver Zinc. This battery is the best high-rate performer in existence. It has been designed to provide from 40 to 55 watt-hours per pound in service and has high-rate discharge with good voltage. Its greatest disadvantages are that it is expensive, and it does not have an exceptionally long cycle life. These shortcomings are expected to be improved in the near future.

e. Silver Cadmium. This battery has similar construction to the silver zinc, but has lower cell voltage and more moderate discharge rate. It is similar in cost to the silver zinc, but better in cycle service due to its cadmium electrode. This battery, as well as the silver zinc, presently is used for space satellite applications, and possibly could have future use in tank-automotive applications.

Section IV. MILITARY APPLICATIONS

12-10. Battery Installation Considerations. The design of a battery installation will vary with the type of vehicle. There are, however, certain design features that can be applied to all vehicles used in a tank-automotive application.

a. The battery always should be mounted in a location that is clean and protected from accumulations of mud, dust, and excess moisture. Protection from the elements is beneficial not only to the operation of the battery itself, but can be the means to prevent unforeseen accidents. For example, if saltwater comes in contact with the positive plates of a damaged lead-acid battery, it will produce chlorine gas. Proper design will avoid the possibility of such an occurrence. Also, provisions for periodic cleaning of the battery installation always should be made.

TA233540

b. The battery should be mounted to facilitate maintenance and provide ready access to the batteries without the need for removing other components. All access plates should be hinged and employ quick-release fasteners when feasible. Allow for adequate clearance so that maintenance personnel wearing arctic clothing can gain access for removal and replacement. Allow enough overhead room to provide for easy, accurate testing and servicing of the batteries.

c. Battery boxes should be designed to protect the vehicle and crew from gases produced during battery charging. These gases are oxygen and hydrogen, which constitute a highly explosive mixture. Thus, adequate ventilation must be provided to allow all gas to escape. This ventilation also is necessary to limit temperature rise in hot climates.

12-11. Battery Installation Configurations (Fig. 12-8).

a. General. Current tank-automotive vehicles always use more than one battery. There are two reasons for this:

(1) Because the standard batteries are 12 volts, two batteries are required to meet the 24-volt requirement of military vehicles.

(2) Additional batteries may be required to meet heavy current demands of certain military vehicles.

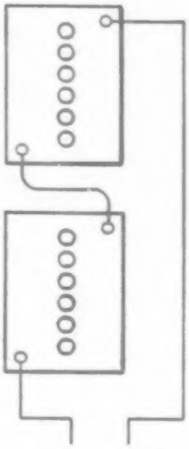
b. Two 12-Volt Batteries in Series. The connection of two 12-volt batteries in series will add their voltages together to deliver 24 volts. It should be noted that the amount of current output, however, will remain the same as for one battery.

c. Four 12-Volt Batteries in Series-Parallel. By taking two pairs of 12-volt batteries connected in series (24 volts for each pair) and connecting them in parallel with each other, a battery pack of 24 volts will result, with twice the current output of each individual battery. This battery configuration is used to meet the demands of heavy-duty use and to provide extra power for cold weather cranking.

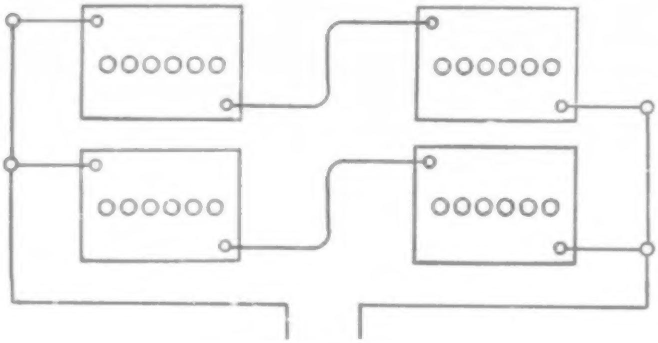
d. Six 12-Volt Batteries in Series-Parallel. This configuration consists of three pairs of 12-volt series-connected batteries in parallel with each other. This configuration will provide 24 volts with three times the current capacity of each individual battery at 24 volts and is used in extreme heavy-duty applications.

261

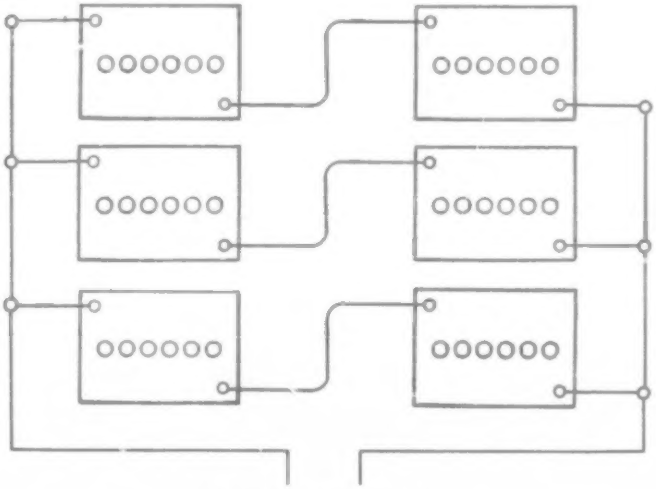
	BATTERY			
	A/HR	QUANT	ARR	V
TRUCK, UTILITY, M151	100	2	SERIES	24
TRUCK, CARGO, M715	100	2	SERIES	24
TANK, M60A1	300	6	SER-PAR	24
APC, M113A1	130	2	SERIES	24
ARMORED RECONAISSANCE VEHICLE, M551	100	2	SERIES	24
HOWITZER, SELF-PROPELLED, M109	200	4	SER-PAR	24



TWO - SERIES



FOUR - SERIES - PARALLEL



SIX - SERIES - PARALLEL

Figure 12-8. Battery Installation Configurations.

TA233541

b. Electric Gage (Fig. 17-13). The instrument panel gage may be the thermostatic-type described in paragraph 17-3a, or the magnetic type described in paragraph 17-3d. The sending unit that is used with each gage type varies as follows:

(1) The sending unit that is used with the thermostatic gage usually contains two bimetallic strips, each of which has a contact point. One bimetallic strip is heated electrically. The other bimetallic strip bends to increase the tension of the contact points. The different positions of the bimetallic strip will create gage readings in the same manner that the different float arm positions of the tank sender will in paragraph 17-3a.

(2) The sending unit that is used with the magnetic gage contains a device called a thermistor. A thermistor is an electronic device whose resistance decreases proportionally as its temperature increases. This type of sending unit also can be used with a thermostatic gage if a voltage-limiting device like the one described in paragraph 17-3b also is used.

c. Mechanical Gage (Fig. 17-14). The gage unit contains a bourdon tube and operates by the same principles as the mechanical oil pressure gage described in paragraph 17-4c. The motivating force of the mechanical temperature gage is a permanently attached capillary tube that connects the gage to a bulb fitted in the engine water jacket. The bulb contains a liquid such as ether, whose vapor pressure is proportional to its temperature. As the temperature increases, the ether boils and expands. The vapor pressure acts on the gage through the capillary tube to produce temperature readings.

d. Indicator Lights (Fig. 17-15). The temperature warning light is used on many vehicles in place of a gage. The indicator light, although not as detailed as a gage, is valuable because of its high visibility in the event of an overheat condition. Because an engine can become damaged permanently or destroyed by operating for short periods while overheated, warning lights often are used as a backup for temperature gages to attract instant attention to a malfunction. The warning light receives battery power through the ignition switch. The circuit to ground is completed through the engine sender switch. The sender switch contains a set of contact points that are operated by the bending of a bimetallic strip that is calibrated to turn on the warning light at approximately 230°F (110°C). Some models also utilize a cold indication light that will indicate to the driver that the engine has not yet reached operating temperature. The light usually is green in color, whereas the hot indication is red. The sending unit for this application has an extra terminal. Internally, the sender has an extra contact. The bimetallic strip simply completes the circuit to the cold light until engine temperature reaches approximately 150°F (65.6°C). The strip then will open the cold light circuit. As long as the temperature of the engine is normal, the bimetallic strip will remain between the contacts for the cold and hot indicator lights.

17-6. Speedometers and Tachometers.

a. Usage. Speedometers and tachometers are used in virtually all types of automotive equipment. Speedometers are used to indicate vehicle speed in miles per hour or kilometers per hour. The speedometer in most cases also contains an odometer. An odometer is a device that keeps a permanent record of the amount of mileage that a vehicle has been used. Some speedometers also contain a trip odometer that can be reset to zero at anytime so that individual trips can be measured. The odometer is calibrated to measure distance in miles or kilometers, depending on the application. A tachometer is a device that is used to measure engine speed in revolutions per minute (rpm). The tachometer also may contain a device known as an engine-hours gage. The engine-hours gage usually is installed on equipment that uses no odometer to keep a record of engine use.

b. Mechanical Speedometers and Odometers. The speedometer and odometer (fig. 17-16) usually are combined into a single unit that is driven by a flexible shaft.

(1) The flexible shaft consists of a flexible outer casing that is made of steel or plastic and an inner drive core that is made of wire-wound spring steel. Both ends of the core are molded square so that they can fit into the driving member at one end and the driven member at the other end and be able to transmit torque.

(2) The flexible shaft, better known as a speedometer cable, usually is driven by gears from the transmission output shaft. When the

360

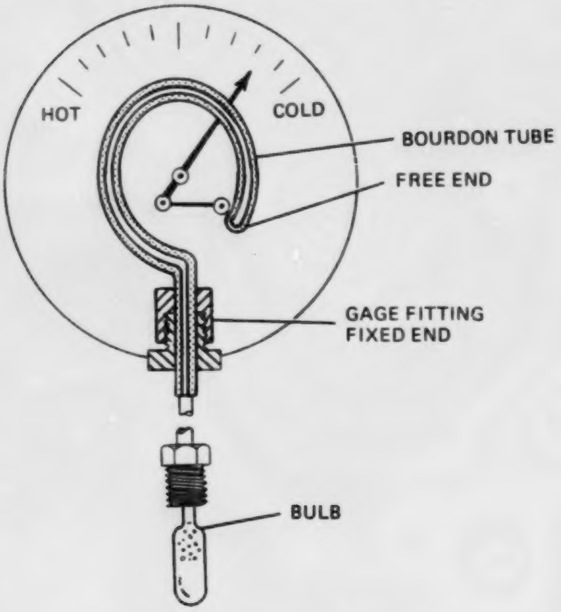

HOT
COLD
BOURDON TUBE
FREE END
GAGE FITTING
FIXED END
BULB

Figure 17-14. Mechanical Temperature Gage..

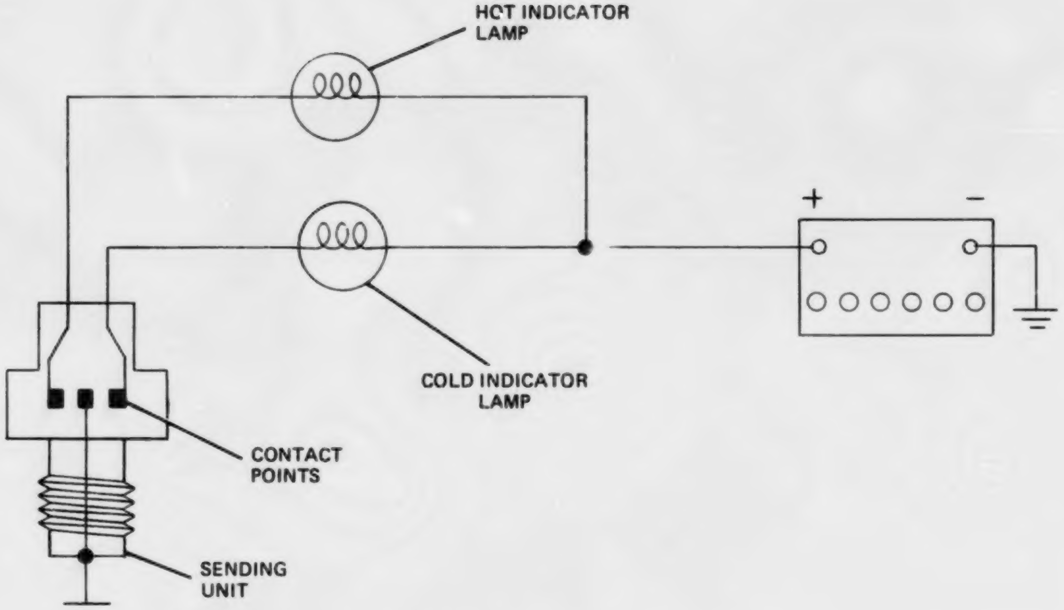

HOT INDICATOR LAMP
+
−
COLD INDICATOR LAMP
CONTACT POINTS
SENDING UNIT

Figure 17-15. Temperature Warning Lights.

TA233629

361

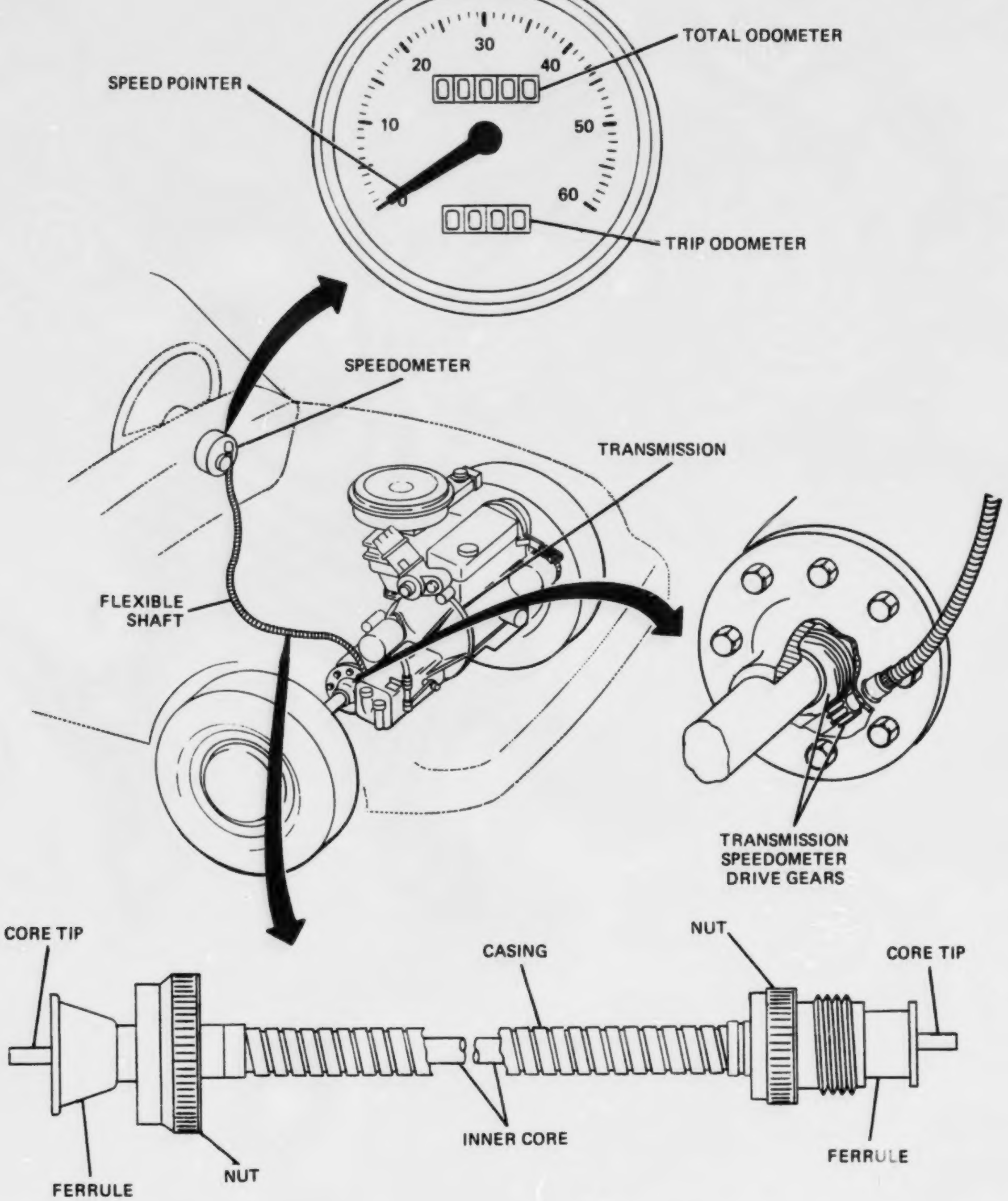

TOTAL ODOMETER
SPEED POINTER
30
20
40
10
50
60
0
00000
0000
TRIP ODOMETER
SPEEDOMETER
TRANSMISSION
FLEXIBLE SHAFT
TRANSMISSION SPEEDOMETER DRIVE GEARS
CORE TIP
CASING
NUT
CORE TIP
INNER CORE
FERRULE
NUT
FERRULE

Figure 17-16. Mechanical Speedometer Installation.

TA233630

gears are selected to drive the speedometer, it is important that the drive axle gear ratio and the diameter of the tires on the drive wheels be taken into consideration so that the speedometer will be driven at the proper speed.

(3) The speedometer (fig. 17-17) consists of a permanent magnet that is rotated by the speedometer cable. Surrounding the rotating magnet is a metal cup that is attached to the speedometer indicating needle. The revolving magnetic field exerts a pull on the cup, causing it to tend to rotate. The rotation of the cup is countered by a calibrated hairspring. The influence of the hairspring and rotating magnetic field on the cup produce accurate speed readings by the needle that is attached to the cup.

(4) The odometer (fig. 17-18) is driven by a series of gears that originate at a spiral gear on the input shaft. The odometer consists of a series of drums with digits printed on their outer circumference that range from zero to nine. The drums are geared to each other so that each time the one furthest to the right makes one revolution, it will cause the one to its immediate left to advance one digit. The second to the right then will advance the drum to its immediate left one digit for every revolution that it makes. This sequence continues to the left through the entire series of drums. The odometer usually contains six digits to record 99,999.9 miles or kilometers. Models with trip odometers usually do not record tenths on the total odometer and therefore will contain five digits. When the odometer reaches its highest value, it will reset to zero automatically. Most new automobiles incorporate a small dye pad in the odometer to color the drum of its highest digit to indicate that total vehicle mileage is in excess of the odometer's capability.

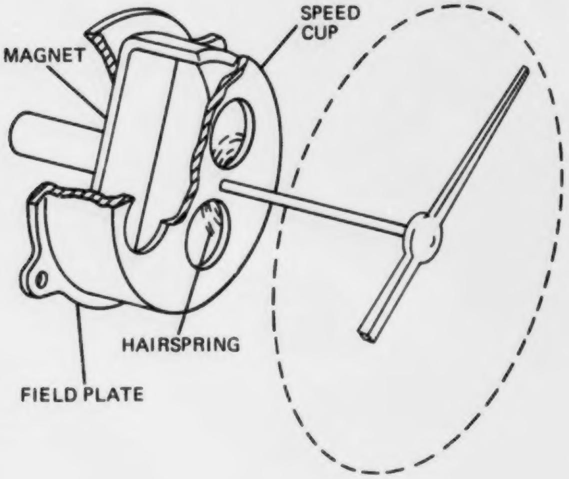


Figure 17-17. Mechanical Speedometer Operation.

(5) The trip odometer also is driven by a series of gears from the input shaft. It usually contains four digits to record 999.9 miles or kilometers before resetting itself to zero. The trip odometer is connected to an external knob and can be reset to zero by the vehicle operator.

c. Mechanical Tachometers and Engine Hours Gage (Fig. 17-19). A mechanical tachometer operates exactly the same as the mechanical speedometer described in paragraph 17-6b. The main difference is that it is driven by the engine and is calibrated to measure engine speed. The engine-hours gage is incorporated in the tachometer in most cases. Its purpose is to keep a record of operating time. It measures in hours to the nearest tenth.

d. Electric Speedometer and Tachometer (Fig. 17-20). The electric speedometer or tachometer utilizes a mechanically driven permanent magnet generator to supply power to a small electric motor. The electric motor then is used to rotate the input shaft of a mechanical speedometer or tachometer whose operation is the same as the one described in paragraph 17-6b. The voltage from the generator will increase proportionally with speed and the motor speed will likewise increase proportionally with voltage, enabling the gages to indicate speed. The signal generator for the speedometer usually is driven by the transmission output shaft through gears. The signal generator for the tachometer usually is driven by the distributor through a power takeoff on gasoline engines. When the tachometer is used with a diesel engine, a special power takeoff provision is made, usually on the camshaft drive.

e. Electronic Speedometers and Tachometers Electronic speedometers and tachometers are self-contained units that use an electric signal from the engine or transmission as an indicator to formulate a reading. They differ from the electric units described in paragraph 17-6d that use the generated signal as the driving force.

TA233631

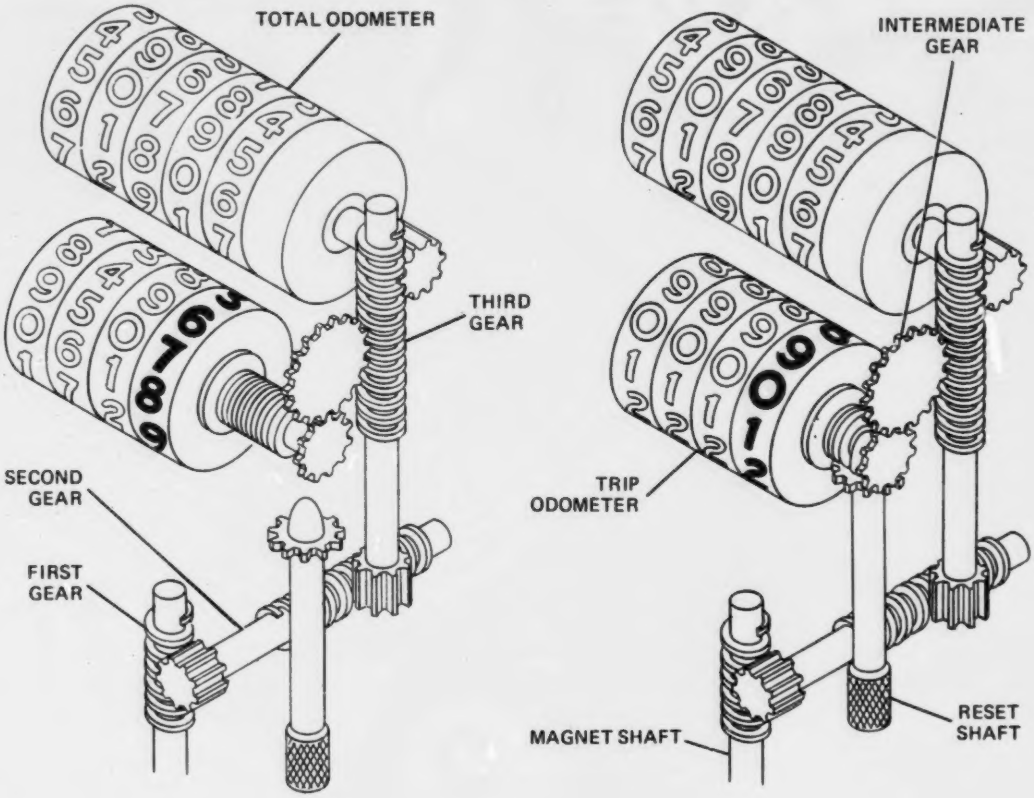

TOTAL ODOMETER
THIRD GEAR
SECOND GEAR
FIRST GEAR
INTERMEDIATE GEAR
TRIP ODOMETER
MAGNET SHAFT
RESET SHAFT

Figure 17-18. Odometer Operation.

The gage unit usually is transistorized and will supply information through either a magnetic analog (dial) or a light emitting diode (LED) digital gage display. The gage unit derives its input signal in the following ways:

(1) An electronic tachometer can obtain a pulse signal from the ignition distributor that switches the coil on and off. This is the most popular signal source for a tachometer that is used on a gasoline engine. The pulse speed at this point will change proportionally with engine speed.

(2) A tachometer that is used with a diesel engine can use the alternating current generated at the stator terminal of the ac generator as a signal. The frequency of the ac current will change proportionally with engine speed.

(3) An electronic speedometer derives its signal from a magnetic pickup coil that has its field interrupted by a rotating pole piece. The signal units operation is the same as the operation of the reluctor and pickup coil described in paragraph 15-6. The pickup coil is located strategically in the transmission case to interact with the reluctor teeth located on the input shaft.

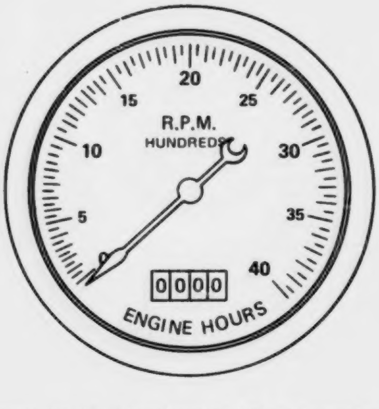

20
15
25
R.P.M.
HUNDREDS
10
30
5
35
0
40
0000
ENGINE HOURS

Figure 17-19. Mechanical Tachometer and Engine Hours Gage.

TA233632

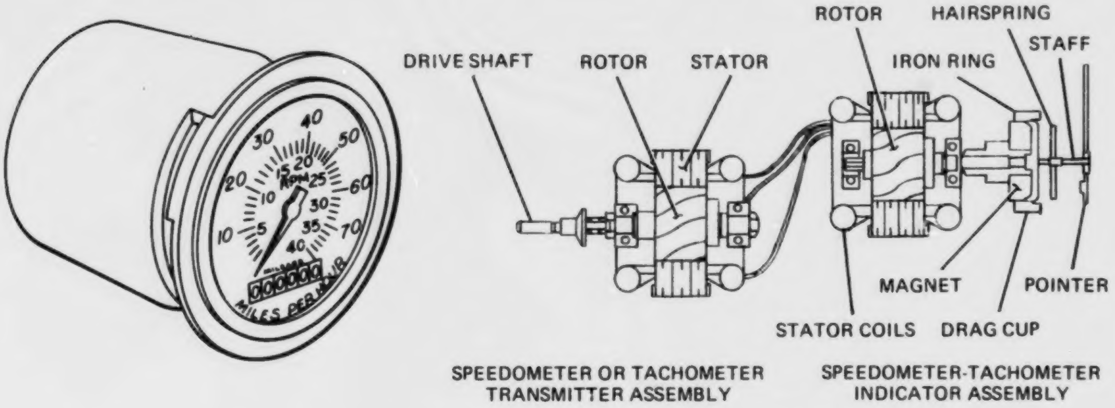

ROTOR
HAIRSPRING
STAFF
DRIVE SHAFT
ROTOR
STATOR
IRON RING
MAGNET
POINTER
STATOR COILS
DRAG CUP
SPEEDOMETER OR TACHOMETER TRANSMITTER ASSEMBLY
SPEEDOMETER-TACHOMETER INDICATOR ASSEMBLY
RPM
MILES PER HOUR

Figure 17-20. Electric Speedometer and Tachometer Operation.

17-7. Tachograph Operation (Fig. 17-21). The tachograph is a device that keeps a complete record of the operation of a vehicle for a 24-hour period. A circular graph is made on a disk by rotating it under three styli that separately record engine speed, vehicle speed, and distance traveled, all versus time. The completed graph can be removed and a blank disk inserted so that the tachograph can be used over again.

In the disk shown in figure 17-21, the vehicle did not move from midnight to approximately 5:37 am. Then the engine was started, revved momentarily to about 1800 rpm, idled at 600 rpm for 6 or 7 minutes, revved to 2100 rpm momentarily, and then shut down at approximately 5:46 am. At 7:10 am the engine was started again and idled for 22 minutes. At 7:32 am the vehicle was moved out, attained a speed of approximately 28 mph

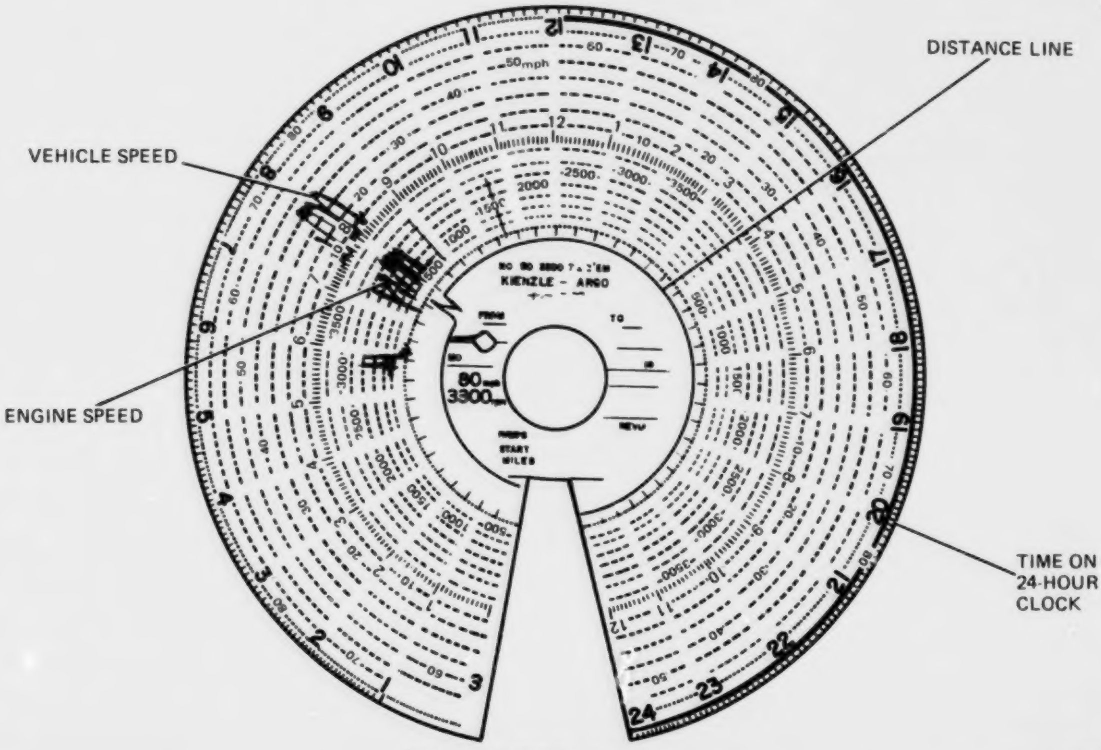

DISTANCE LINE
VEHICLE SPEED
ENGINE SPEED
TIME ON 24-HOUR CLOCK
KIENZLE - ARGO
FROM
TO
80 mph
3300 rpm
START
MILES

Figure 17-21. Tachograph.

TA233633

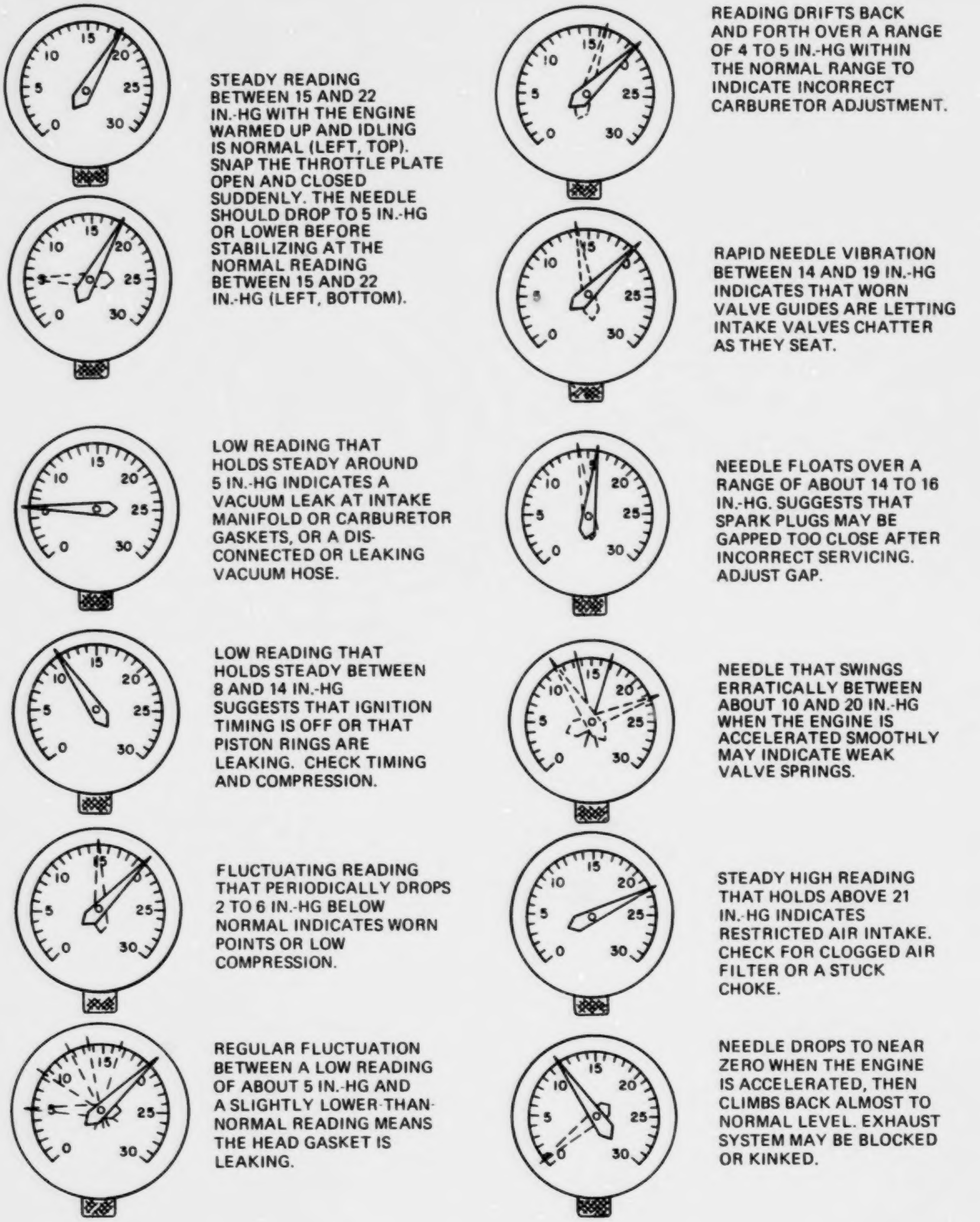
(45.05 km/h), and then stopped and idled for 8 minutes. The vehicle then was moved out again, accelerated to approximately 45 mph (72.4 km/h) and did stop-and-go driving for about 32 minutes, accelerating from 0 to 45 mph (72.4 km/h) three times and traveling about 15 miles (24.13 km). At 8:11 am it stopped, after having traveled approximately 15 miles (24.13 km). It idled for about 48 minutes and then was shut down at 9 am.

17-8. Vacuum Gage (Fig. 17-22). A vacuum gage measures the difference in pressure between the intake manifold and the atmosphere in inches of mercury (inHg). The unit of measure is derived from applying a vacuum to the top end of a tube whose bottom end is dipped in mercury. The reading then is obtained by measuring how far in inches the mercury rises in the tube. A vacuum gage is very useful for:

a. Engine Diagnosis. A vacuum gage can locate things such as valve malfunctions, manifold vacuum leaks, or improperly adjusted ignition timing.

b. Driving for Maximum Efficiency. Because intake manifold vacuum decreases proportionally with engine load increases, the vacuum gage can be used as a driving aid to attain maximum fuel economy and engine life.

366



STEADY READING BETWEEN 15 AND 22 IN.-HG WITH THE ENGINE WARMED UP AND IDLING IS NORMAL (LEFT, TOP). SNAP THE THROTTLE PLATE OPEN AND CLOSED SUDDENLY. THE NEEDLE SHOULD DROP TO 5 IN.-HG OR LOWER BEFORE STABILIZING AT THE NORMAL READING BETWEEN 15 AND 22 IN.-HG (LEFT, BOTTOM).

READING DRIFTS BACK AND FORTH OVER A RANGE OF 4 TO 5 IN.-HG WITHIN THE NORMAL RANGE TO INDICATE INCORRECT CARBURETOR ADJUSTMENT.

RAPID NEEDLE VIBRATION BETWEEN 14 AND 19 IN.-HG INDICATES THAT WORN VALVE GUIDES ARE LETTING INTAKE VALVES CHATTER AS THEY SEAT.

LOW READING THAT HOLDS STEADY AROUND 5 IN.-HG INDICATES A VACUUM LEAK AT INTAKE MANIFOLD OR CARBURETOR GASKETS, OR A DISCONNECTED OR LEAKING VACUUM HOSE.

NEEDLE FLOATS OVER A RANGE OF ABOUT 14 TO 16 IN.-HG. SUGGESTS THAT SPARK PLUGS MAY BE GAPPED TOO CLOSE AFTER INCORRECT SERVICING. ADJUST GAP.

LOW READING THAT HOLDS STEADY BETWEEN 8 AND 14 IN.-HG SUGGESTS THAT IGNITION TIMING IS OFF OR THAT PISTON RINGS ARE LEAKING. CHECK TIMING AND COMPRESSION.

NEEDLE THAT SWINGS ERRATICALLY BETWEEN ABOUT 10 AND 20 IN.-HG WHEN THE ENGINE IS ACCELERATED SMOOTHLY MAY INDICATE WEAK VALVE SPRINGS.

FLUCTUATING READING THAT PERIODICALLY DROPS 2 TO 6 IN.-HG BELOW NORMAL INDICATES WORN POINTS OR LOW COMPRESSION.

STEADY HIGH READING THAT HOLDS ABOVE 21 IN.-HG INDICATES RESTRICTED AIR INTAKE. CHECK FOR CLOGGED AIR FILTER OR A STUCK CHOKE.

REGULAR FLUCTUATION BETWEEN A LOW READING OF ABOUT 5 IN.-HG AND A SLIGHTLY LOWER-THAN-NORMAL READING MEANS THE HEAD GASKET IS LEAKING.

NEEDLE DROPS TO NEAR ZERO WHEN THE ENGINE IS ACCELERATED, THEN CLIMBS BACK ALMOST TO NORMAL LEVEL. EXHAUST SYSTEM MAY BE BLOCKED OR KINKED.

Figure 17-22. Vacuum Gage Readings.

TA233634

367

Section II. HORNS

17-9. Principles of Operation (Fig. 17-23). The most common type of horn is the vibrator type, in which the general principle of operation is the same as that of a vibrating coil. A vibrating diaphragm is operated by the coil that also operates the contacts that break the circuit.

Magnetism from the coil pulls the diaphragm toward it when the contacts are closed. The contacts then are pulled open by the coil, reducing the magnetism and allowing the diaphragm to return to its normal position. When the contacts are closed again, a new surge of current induces magnetism in the coil and starts a second movement of the diaphragm. This cycle is repeated rapidly. The vibrations of the diaphragm within an air column produce the note of the horn. Tone and volume adjustments are made by loosening the adjusting locknut and turning the adjusting nut. This very sensitive adjustment controls the current consumed by the horn. Increasing the current increases the volume. However, too much current will make the horn sputter and may lock the diaphragm.

17-10. Dual Horns. In dual horns, one horn with a low pitch is blended with another horn with a high pitch. These horns, although operated electrically, produce a sound closely resembling that of an air horn. The sound frequency of the low-pitch horn is controlled by a long air column and the high-pitch horn sound frequency is controlled by a short air column. The air column is formed by the projector and a spiral passage cast into the base of the horn.

17-11. Controls (Fig. 17-24). The current draw of a horn is very high, therefore, usually it is operated by a relay. The control switch usually is mounted on the steering wheel and may be controlled by a button or a horn ring.

a. The horn receives electric current through the ignition switch and the relay contact points. The relay contact points normally are open, keeping the horn from operating.

b. The relay contact points are closed whenever the magnetic coil is energized. The magnetic coil receives positive battery current from the ignition switch. The horn switch completes the circuit to ground.

17-12. Air Horns (Fig. 17-25). The air horn is a trumpetlike device that operates from compressed air. Air horns usually are used on vehicles that are equipped with airbrakes because they can operate from the vehicle's compressed

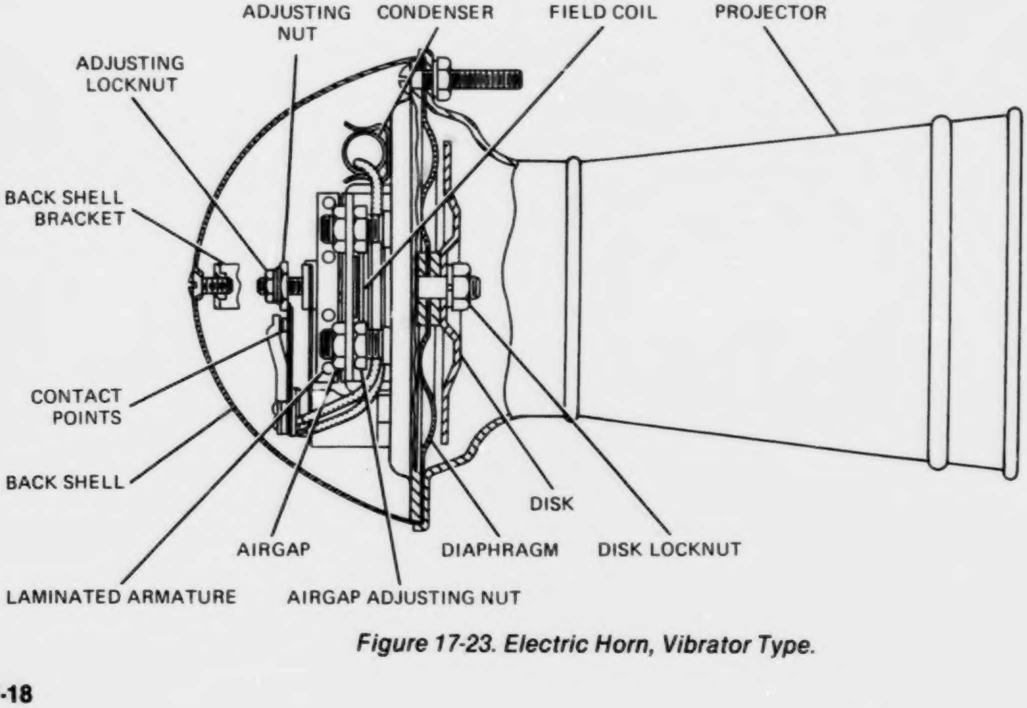


Figure 17-23. Electric Horn, Vibrator Type.

TA233635

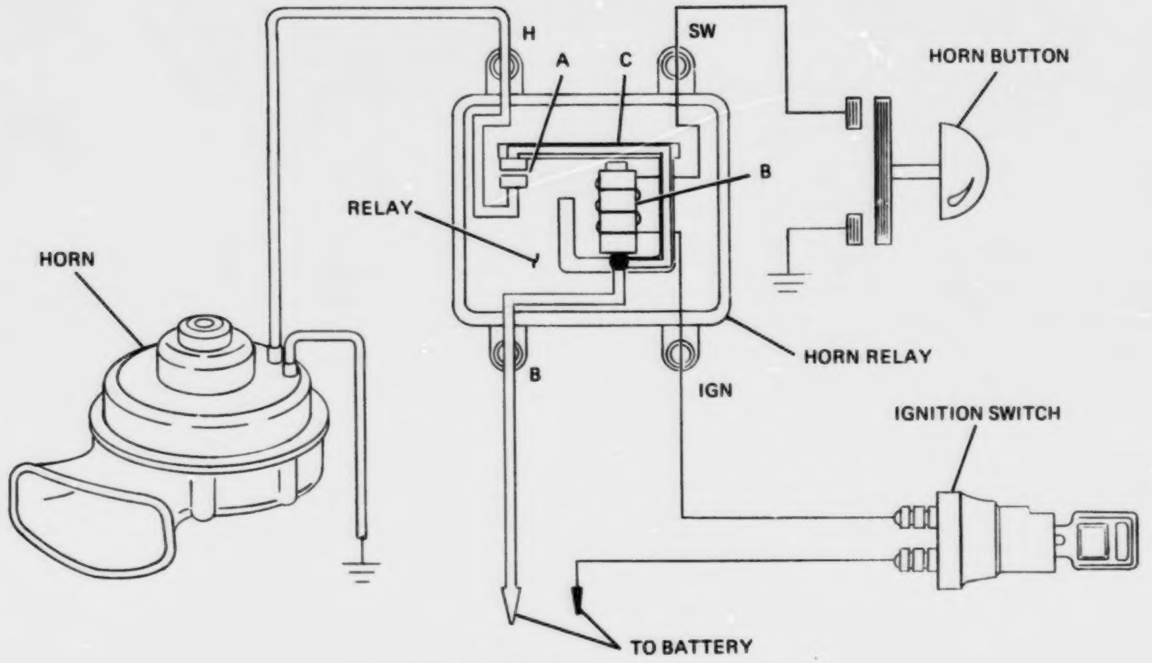

H
SW
A
C
HORN BUTTON
B
RELAY
HORN
HORN RELAY
B
IGN
IGNITION SWITCH
TO BATTERY

Figure 17-24. Horn Circuit Using a Relay.

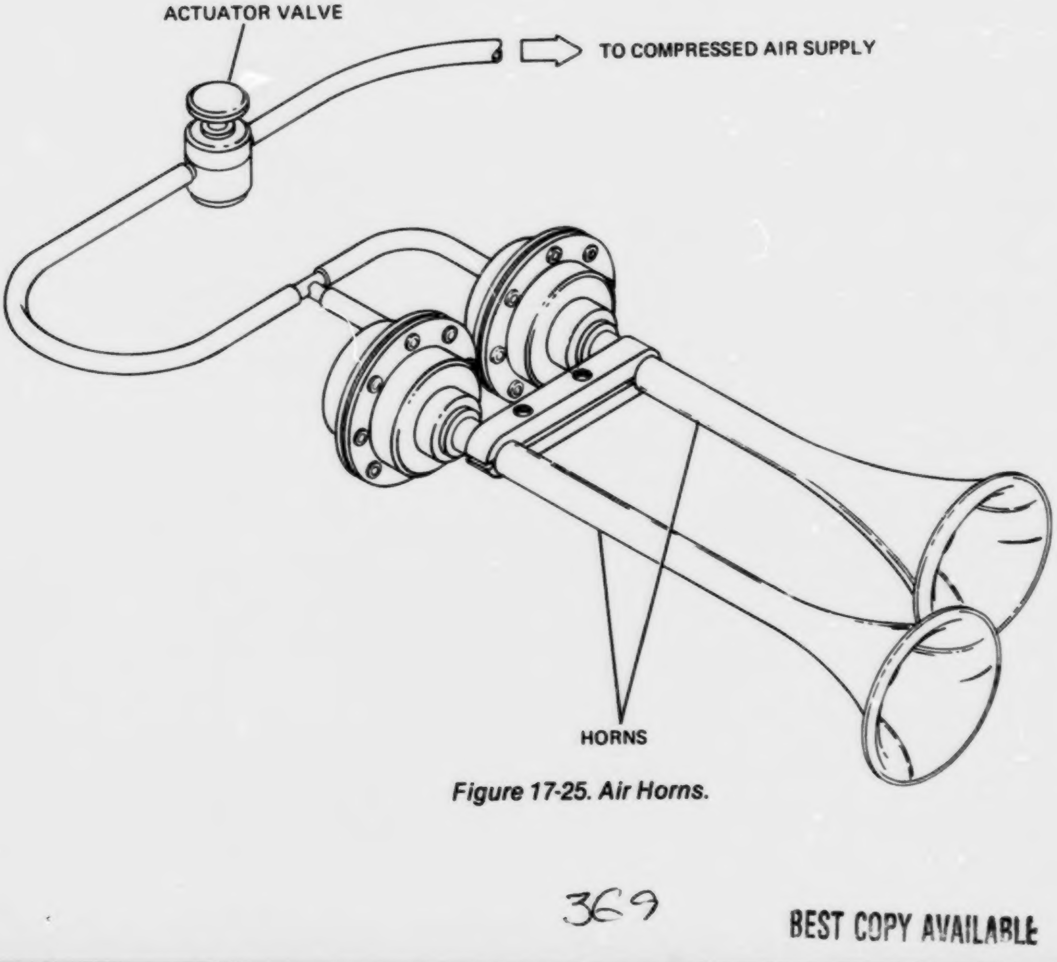

ACTUATOR VALVE
TO COMPRESSED AIR SUPPLY
HORNS

Figure 17-25. Air Horns.

TA233636

air system. Air horns also may have their own compressed air system. The air horn is controlled by an air valve.

17-13. Backup Alarms. Large vehicles sometimes utilize an air or electric horn at the rear that is actuated when the transmission is shifted to reverse. The purpose of this is to warn pedestrians when the vehicle is backing up.

Section III. WINDSHIELD WIPERS

17-14. Vacuum Wipers. Vacuum-operated windshield wipers utilize the negative pressure that is present in the engine's intake manifold as a vacuum source to operate the windshield wiper motor. Because the pressure in the intake manifold varies with engine loading, the speed of the wipers varies greatly with engine loading to the extent that the windshield wipers actually will stop when the engine is loaded heavily, such as when the vehicle is climbing a hill. Some vehicles utilize an auxiliary vacuum pump to help alleviate this problem. This pump usually is built into the engine's fuel pump (para 4-3). The windshield wiper motor transmits its power to the transmission linkage in the form of reciprocating motion. The transmission for a vacuum system utilizes a pulley and cable system to link the motor to the windshield wiper arms and blades. Because of the erratic operation of the vacuum wiper system, it has been replaced almost completely by the electric wiper system in modern automotive applications.

17-15. Electric Wipers (Fig. 17-26). Electric windshield wipers are the most popular type for use on modern automotive equipment. Electric windshield wipers operate at a constant, easily controlled speed, making them much more desirable than their vacuum counterparts. One of the drawbacks to using electric windshield wipers in early automotive equipment was the heavy electric current requirements that their motor

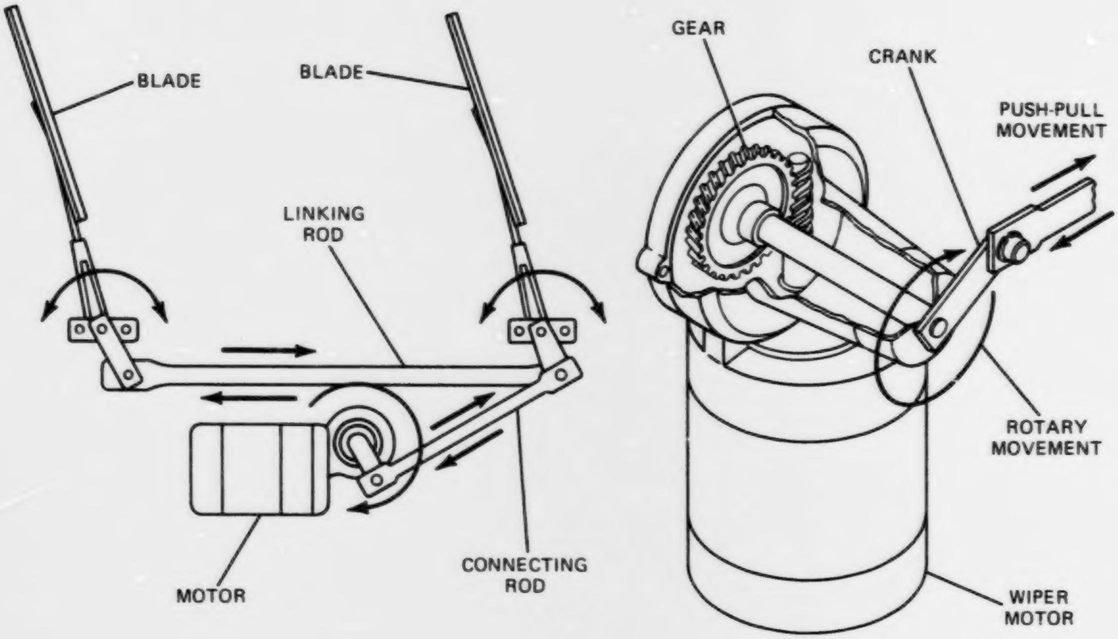


Figure 17-26. Electric Wipers.

TA233637

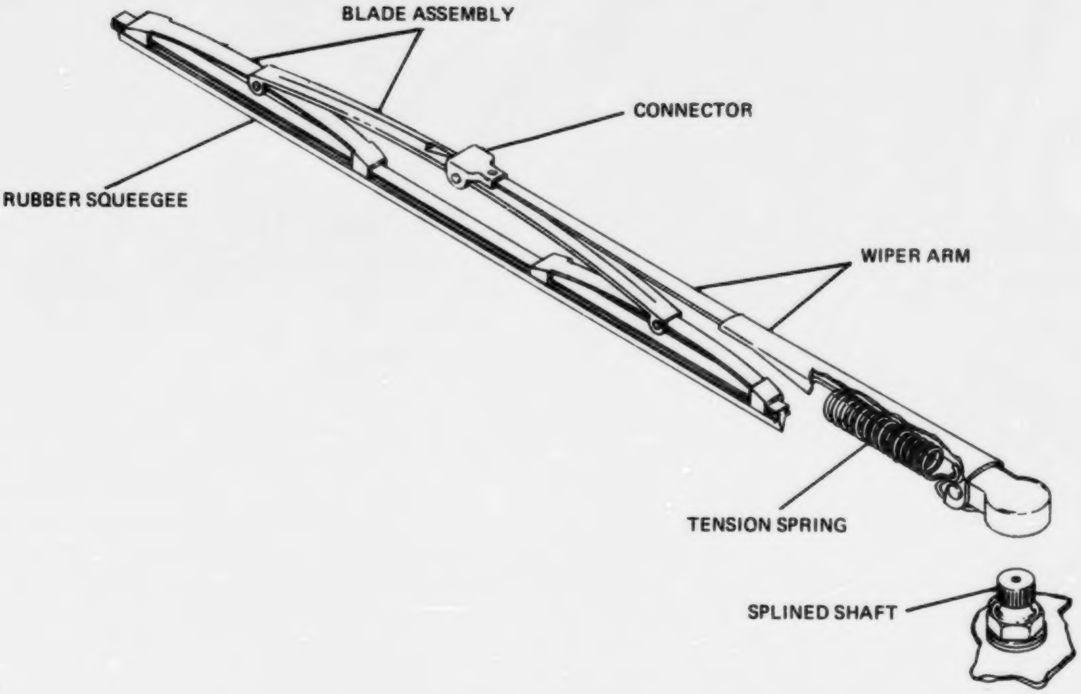


Figure 17-27. Wiper Arm and Blade.

placed on the vehicle's 6-volt electrical system. This problem was solved as 12-volt electrical systems became standard. The electric wiper motor, through a worm gear, drives a shaft that is connected to a crank. The circular motion of this crank is transformed into reciprocating motion by the wiper transmission to operate the wiper arms. In addition to the control switch that is used to control the windshield wipers, a separate, mechanically operated park switch also is incorporated into the motor. The purpose of this switch is to provide power to the wiper motor long enough to return the wiper arms and blades to a retracted position whenever they are switched off by the operator.

17-16. Air-Operated Wipers. Air-operated windshield wipers are used almost exclusively on heavy vehicles that are equipped with a compressed air supply system to operate the wiper motor. Air-operated wiper motors directly produce the reciprocating motion that is required to operate the wiper arms. Because of this, they often are mounted in a position that allows a wiper arm to be connected directly to them.

17-17. Wiper Arm and Blade (Fig. 17-27). The wiper arm fits onto a splined shaft on the wiper transmission and is spring loaded to press the blade against the windshield. The blade is a flexible rubber squeeze-type device. It is spring steel backed and is suspended from the arm by a mechanism that is designed to maintain total contact with the windshield throughout the stroke.

Section IV. ACCESSORIES

17-18. Auxiliary Power Receptacle (Fig. 17-28). The auxiliary power receptacle usually is installed at the right-rear corner of the cab body, near the vehicle batteries. The receptacle has two insulated prongs, each connected by cable to one battery terminal. This means that the receptacle is wired in parallel with the battery. It is used to facilitate charging of the batteries from an external source or the connecting of additional electrical power from an external source to operate electrical components on the vehicle. The receptacle greatly simplifies these proce-

TA233638

371

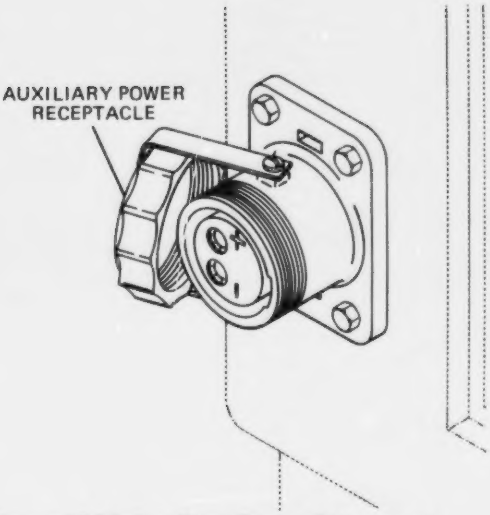


Figure 17-28. Auxiliary Power Receptacle.

dures because it is necessary only to unscrew the receptacle cap and plug in the connector to make the connections. No disconnecting and reconnecting of the battery cable is necessary.

17-19. Heater, Defroster, and Ventilation Mechanisms.

a. General (Fig. 17-29). The heater, defroster, and ventilation mechanisms usually are combined into one unit to make up a complete system. The unit, which is called a heater unit, consists of a chambered box containing a heater core (para 17-19b) and control doors to allow the operator to select the desired mode of operation. The outside of the box contains openings for:

(1) Outside air intake, so that fresh air can be drawn into the vehicle.

(2) Interior air intake, so that air can be recirculated.

(3) Defroster outlets, so that forced air can be provided to clear the windshield.

(4) Heater outlets, so that heated air can be provided, usually at floor level.

(5) Ventilation outlets so that air can be forced into the passenger compartment at instrument panel level. An electric blower motor also is combined with this unit to provide air movement.

b. Heater Core (Fig. 17-30). The heater core is a component that transfers heat from the engine coolant to the passenger compartment. Its construction is similar to a radiator (para 9-6), except that it is on a much smaller scale. The heater core fits into the heater unit and is connected to the engine's cooling system by two hoses called heater hoses. The connection to the engine's coolant passages is made at strategic points that will cause the engine's water pump to force a constant supply of engine-heated coolant through the heater core. The heater core feed line is fitted with a control valve that can be controlled by the operator. The purpose of the valve is to open, restrict, or shut off the coolant flow through the heater core to control the heater temperature. The temperature control valve can be either cable operated, or it can be operated by a vacuum-actuated diaphragm that receives its vacuum supply from the engine.

c. Mode Door (Fig. 17-29). The mode door selects the heater unit's mode of operation. As the door is moved through its full travel, air is ducted through the heat, vent, or defrost outlets.

d. Fresh-Air Door (Fig. 17-29). The fresh-air door selects either a fresh-air or interior-air (recirculate) intake for the heater unit.

e. Door Controls. The heater control doors can be controlled two different ways:

(1) *Cable Operated (Fig. 17-31).* The doors can be operated by cable from the instrument panel. Cable-operated doors usually have the advantage of crossover operation. This means that the fresh-air door, for example, can be positioned halfway between the fresh air and recirculate intakes, allowing a blend of fresh and recirculated air.

(2) *Vacuum Operated (Fig. 17-32).* The doors can be operated by actuators that are powered by a vacuum supply from the engine. This vacuum supply is routed to the actuators by rubber hoses that first pass through control valves in the instrument panel. The control valves usually are built into a master control switch that is controlled by the operator. The advantage to this control system is that it is much easier to route the rubber supply hoses in the tight confines of the instrument panel area than it is to route control cables that will bind if kinked.

TA233639

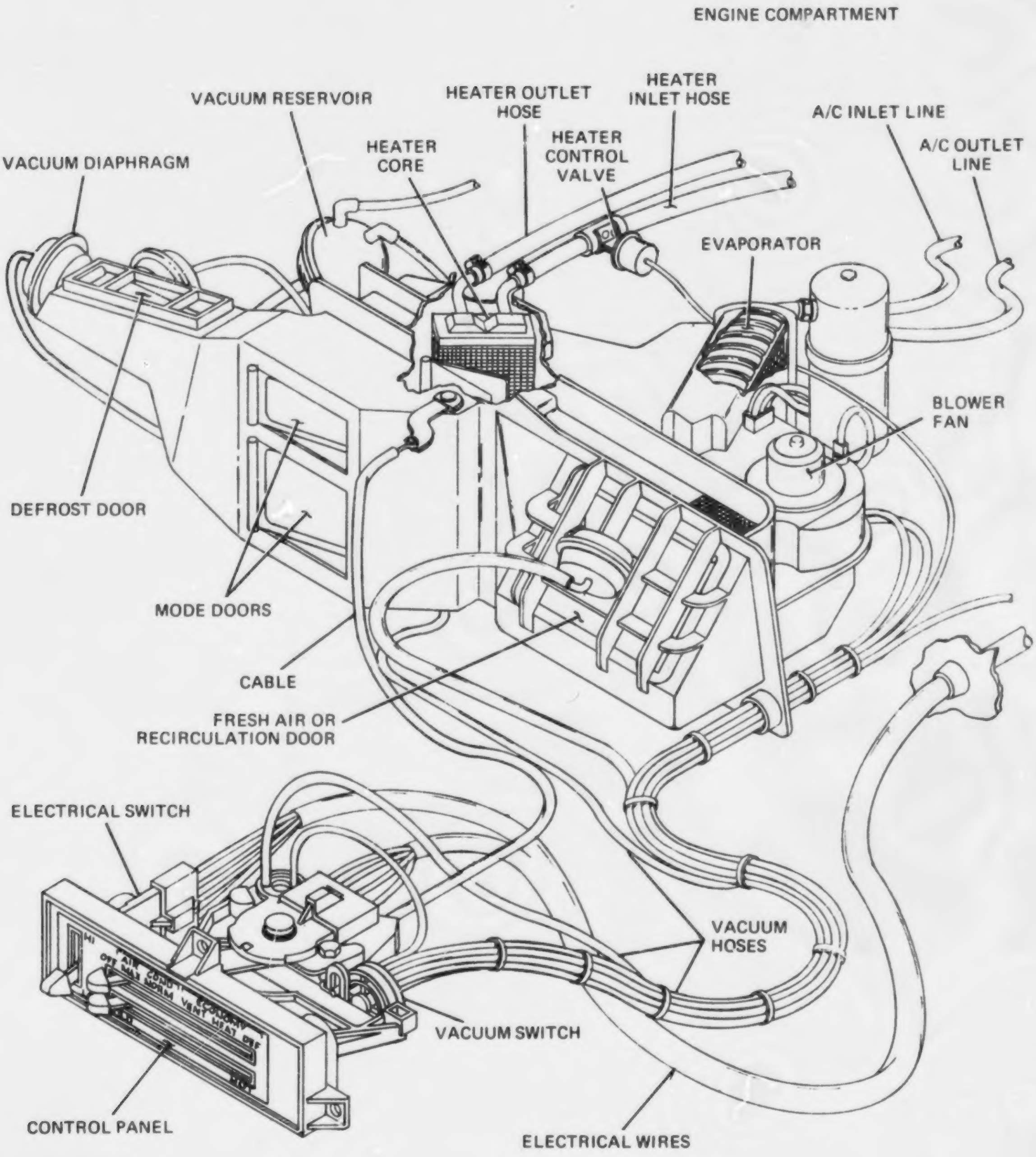

ENGINE COMPARTMENT
VACUUM RESERVOIR
HEATER OUTLET HOSE
HEATER INLET HOSE
A/C INLET LINE
VACUUM DIAPHRAGM
HEATER CORE
HEATER CONTROL VALVE
A/C OUTLET LINE
EVAPORATOR
BLOWER FAN
DEFROST DOOR
MODE DOORS
CABLE
FRESH AIR OR RECIRCULATION DOOR
ELECTRICAL SWITCH
HI
AIR COND
ECONOMY
OFF MAX NORM VENT HEAT DEF
VACUUM HOSES
VACUUM SWITCH
CONTROL PANEL
ELECTRICAL WIRES

Figure 17-29. Typical Heating Ventilation and Air-Conditioning System.

TA233640

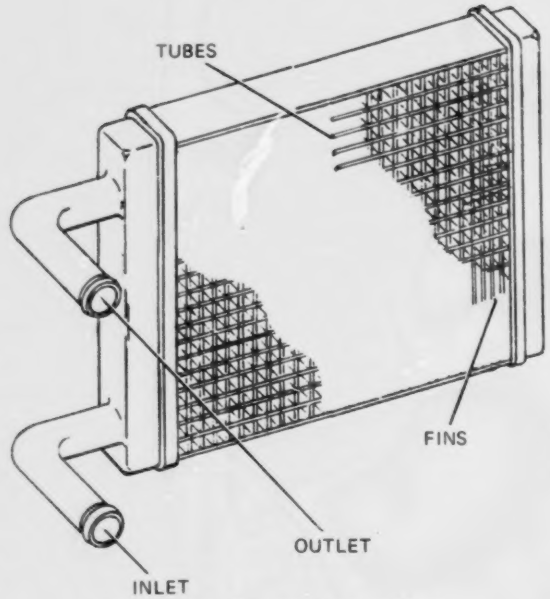


Figure 17-30. Typical Heater Core.

f. Blower Motor. The blower motor is a simple electric motor that drives a circular fan. This circular fan commonly is referred to as a squirrel cage. The controls of the blower usually include a three- or four-position switch providing various speed choices to the operator. The switch, in conjunction with a multiple element resistor, provides the circuitry to make these motor selections possible.

17-20. Auxiliary Heaters.

a. Engine Compartment Heaters. The engine compartment, particularly in vehicles equipped for arctic operation, contain one or more auxiliary heating devices. The most common devices are:

(1) *Water Jacket Heater.* The water jacket heater is an electric resistance-type heater that operates usually from an external 110-volt power supply. The heating unit usually is installed in place of one of the cylinder block core hole plugs.

(2) *Engine Oil Heater.* The engine oil heater is also an electric resistance-type heater that operates from an external 110-volt power supply. The engine oil heater is a bayonet-type device that fits in the engine in place of the dipstick.

(3) *Blanket Heaters.* Engine compartment components also can be heated by blanket-type electric heaters. These devices are used to heat the battery or can be used to cover the engine, retarding engine cool down after operation.

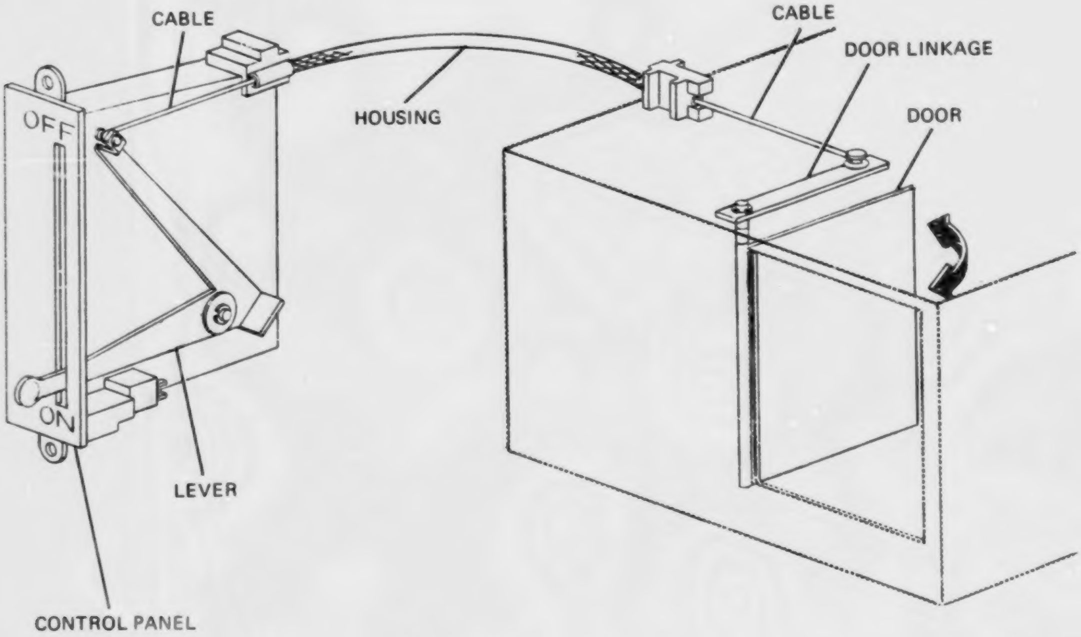


Figure 17-31. Cable-Operated Mode Doors.

TA233641

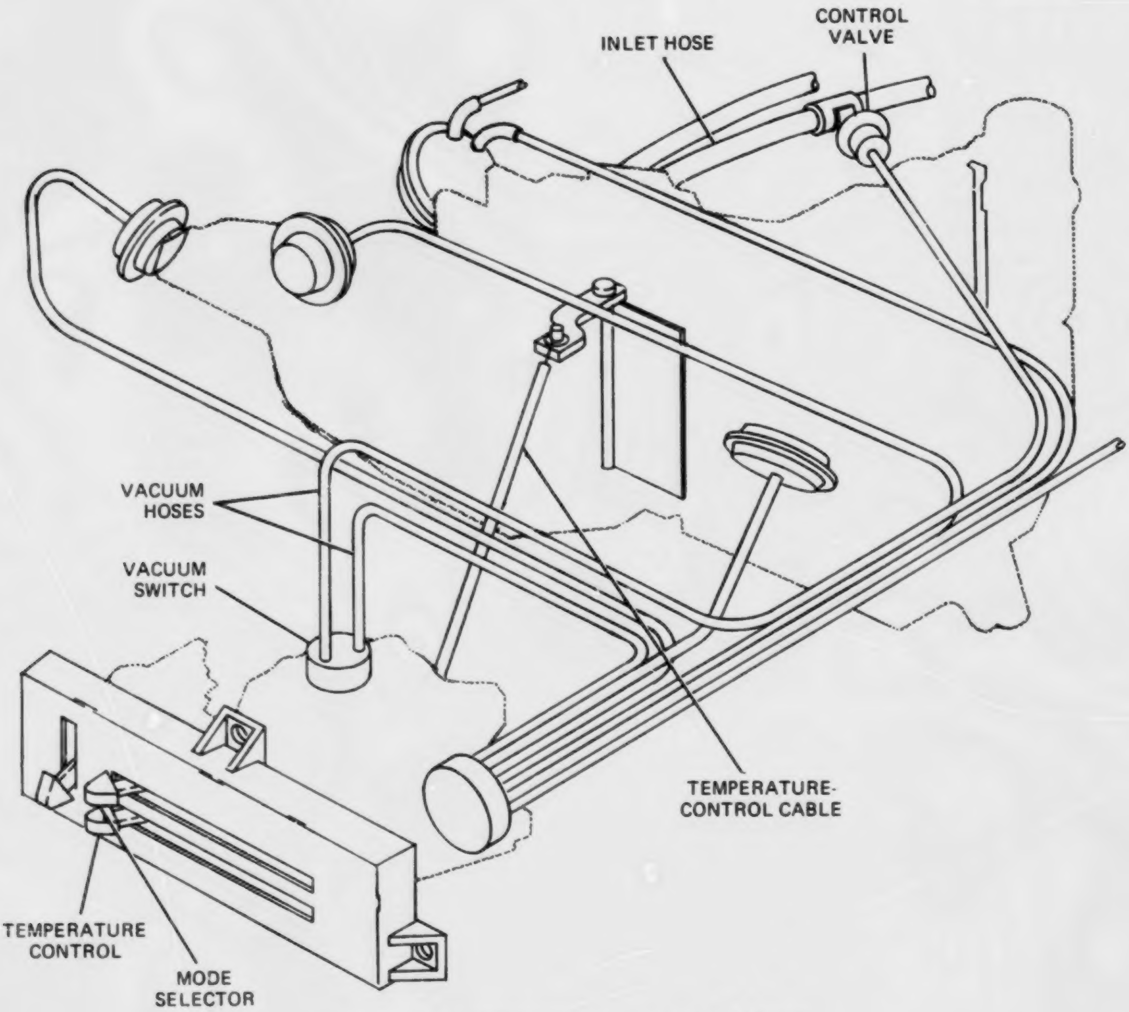

INLET HOSE
CONTROL VALVE
VACUUM HOSES
VACUUM SWITCH
TEMPERATURE-CONTROL CABLE
TEMPERATURE CONTROL
MODE SELECTOR

Figure 17-32. Vacuum-Operated Mode Doors.

b. Interior Heaters. Auxiliary heaters also are used to heat the vehicle's interior compartments. There are two basic types.

(1) *Self-contained.* These usually are propane or butane space heaters. For portable shelters, an electric-type space heater will be used. This type of heater requires an external power supply.

(2) *Supplemental Hot Water Heaters.* These heaters contain a fan motor and a heater core (para 17-19). They are connected to the engine's cooling system and operate by the same principles as the vehicle's main heater.

TA233642

375

Section V. AUTOMOTIVE WIRING

17-21. General.

a. Electrical power and control signals must be delivered to electrical devices reliably and safely so that the electrical system functions are not impaired or converted to hazards. This goal is accomplished through careful circuit design, prudent component selection, and practical equipment location.

b. The list of common equipment used to fulfill power distribution requirements in military vehicles includes single-conductor cable, multiconductor cable, bus bars, terminal blocks, terminals, and connectors. In order to facilitate the successful application of such equipment, guidelines for the design of main power distribution circuits, conductor selection and routing practices, wiring and cable assembly requirements, human factors, environmental considerations, circuit protection requirements, and circuit identification techniques are discussed in this section. Included are the general power distribution considerations necessary for effecting good performance, economy, and safety in a vehicle electrical system design.

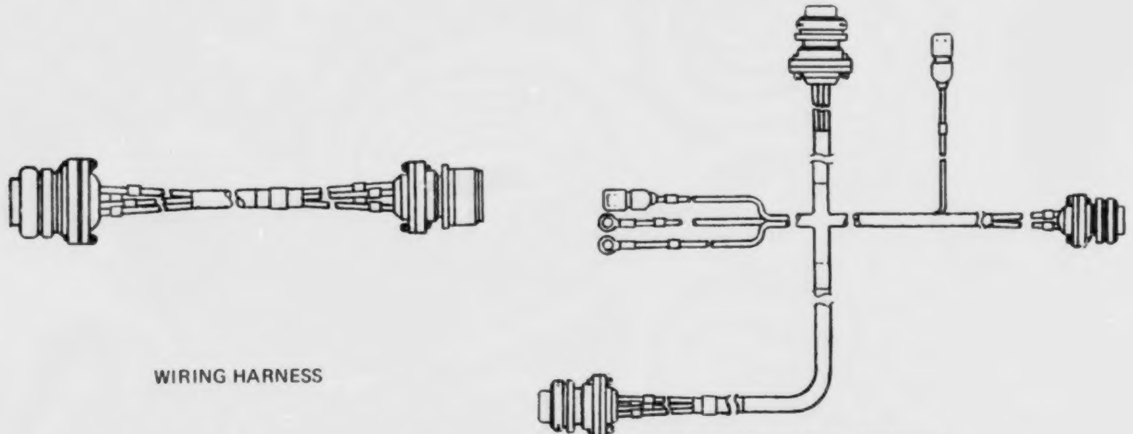
17-22. Wiring Harnesses.

a. General (Fig. 17-33). Wiring assemblies consist of wires and cables of definitely prescribed length, assembled together to form a subassembly that will interconnect specific electrical components and/or equipment. There are two basic types of wiring assemblies:

(1) *Cable Assembly.* The cable assembly consists of a stranded conductor with insulation or a combination of insulated conductors enclosed in a covering or jacket from end to end. Terminating connections seal around the outer jacket so that the inner conductors are isolated completely from the environment experienced by the outer jacket. Cable assemblies may have two or more ends.

(2) *Wiring Harness.* Wiring harness assemblies contain two or more individual conductors laid parallel or twisted together and wrapped with binding materials such as tape, lacing cord, and wiring ties. The binding materials do not isolate the conductors from the environment completely, and conductor terminations may or may not be sealed. Wiring harnesses also may have two or more ends.

b. Wiring Harness Bindings. Several methods are employed to bind the wire bundles together in wiring harness assemblies. Each method has an intended or preferred application in military vehicles.



WIRING HARNESS

WIRING HARNESS, BRANCHED

Figure 17-33. Wiring Harnesses.

TA233643

(1) *Tape Binding (A, Fig. 17-34).* This binding is intended for vehicle interior wiring applications where wires are unprotected, and an additional measure of snag protection and abrasion resistance is required. Cables are bound together with one-half overlapping turns of tape. Tape, Type EF-9, Black, MIL-I-5126, has demonstrated suitable low-temperature flexibility (-10°F cold bend) in the military environment.

(2) *Spaced Bindings (B, Fig. 17-34).* This binding is intended for vehicle interior wiring in protected locations, or in junction and control box applications. Cables are bound together with one-half overlapping turns of tape in spaced intervals. Tape should form 2- to 2.25-in. wrap lengths spaced at 8- to 12-in. intervals.

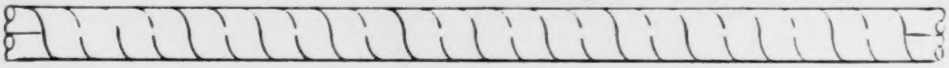
(3) *Spaced Bindings – Heat-Shrinkable Tubing (C, Fig. 17-34).* One alternative method for spaced binding uses sleeving in lieu of tape. A heat-shrinkable modified neoprene rubber sleeving, MIL-I-23053/1, has demonstrated suitable low-temperature flexibility (-55°C brittleness) in the military environment and the cables are bound together with 0.75- to 1.25-in. lengths of the heat-shrinkable sleeving spaced at 8- to 12-in. intervals.

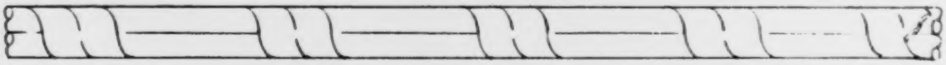
(4) *Spaced Bindings – Cable Ties (D, Fig. 17-34).* Another alternative spaced-binding method uses wire ties or straps. Cable straps, adjustable, self-clinching, MS3367-1, MS3367-3, MS3367-4, or MS3367-5 are suitable for this application. Cables are bound together with straps spaced at 8- to 12-in. intervals.

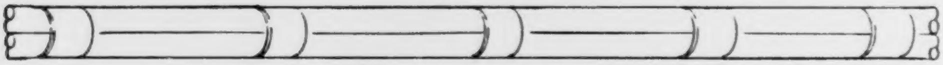
(5) *Laced Bindings (E, Fig. 17-34).* Lacing is intended for wiring used in junction and control box applications. Lacing cord in accordance with MIL-T-43435, Size 3, Type I, Finish B, Waxed, Color Optional, has performed satisfactorily in the military environment.

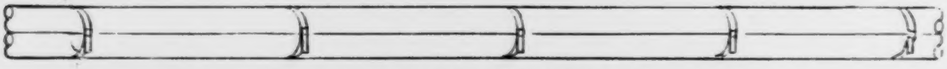
(6) *High-Temperature Bindings (F, Fig. 17-34).* This binding method is intended for harnesses used on engines, transmissions, or other systems where additional protection against high temperature is required. Cables are covered, or bound together with insulating sleeving. Sleeving ends and junctions are bound to cables with one-half overlapping turns of tape. Tape endings must overlap fully.

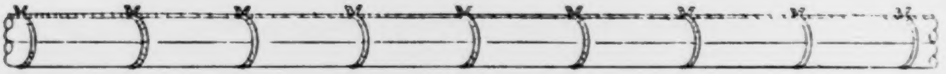
Insulating sleeving, electrical, Class 200, Type C, Category C or D, MIL-I-3190, has demonstra-


A. FULL TAPE BINDING


B. SPACED BINDING (TAPE)


C. SPACED BINDING (SLEEVING)


D. SPACED BINDING (STRAPS)


E. LACED BINDING

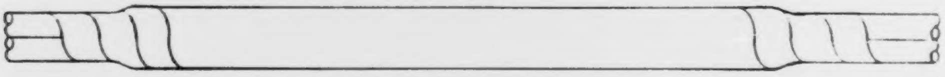

F. HIGH-TEMPERATURE BINDING

Figure 17-34. Harness Bindings.

TA233644

ted suitable high-temperature and humidity resistance in these applications. Tape 19207-10886484 has demonstrated adhesive qualities that withstand steam cleaning and the oily, high-temperature environment associated with vehicle power packs.

17-23. Wiring Harness Identification (Fig. 17-35). Wires in an electrical system should be identified by a number, color, or code to facilitate tracing circuits during assembly, troubleshooting, or rewiring operations. This identification should appear on wiring schematics and diagrams and whenever practical on the individual wire. The assigned identification for a continuous electrical connection should be retained on a schematic diagram until the circuit characteristic is altered by a switching point or active component. An extension of this system involves the use of suffix letters on wiring diagrams and wiring assemblies to identify the segments of wires between terminals and connector contacts. The use of suffix letters is advantageous when it is necessary to identify several individual wires of a common circuit that are bound in the same harness.

Tank-automotive electrical circuits have been identified over the years with unique numbers for specific circuits, based on the premise that maintenance personnel would become familiar with wire numbers for these circuits and this familiarity would facilitate their ability to service a variety of vehicles. Furthermore, common standard automotive electrical components in the supply system such as headlight, taillight, and stoplight switch assemblies are marked with these standard wire numbers. Therefore, these numbers should be used to the maximum extent practical for the identification of circuits in future military vehicle electrical systems. There are several practical methods used to apply wire identification characters on wiring assemblies. Four of the commonly employed methods are:

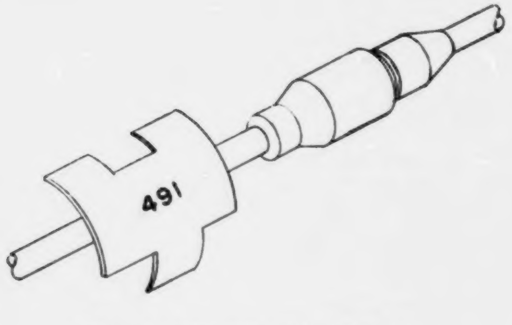


Figure 17-35. Wire Identification.

a. Lettering may be hot stamped per MIL-M-81531, with 0.05-in. minimum height type, directly on the wire or cable insulation using white letters on dark backgrounds or black letters on light backgrounds.

b. Lettering may be hot stamped per MIL-M-81531, with 0.05-in. minimum height type, on MIL-I-23053/2 heat-shrinkable sleeving, length and diameter as required, assembled over the wire insulation.

c. Lettering may be indented or embossed with 0.093-in. minimum height type on band, marker blank, MS39020, style and length as required, in accordance with MIL-STD-130. Of these, the metal marker bands with indented or embossed characters are the most durable and they remain legible even if painted over.

17-24. Wire Terminal Ends.

a. General (Fig. 17-36). Wire lug terminals are divided into two major classes: the solder type; and the solderless type, which also are called the pressure or crimp type. The solder type has a cup in which the wire is held by solder permanently, whereas the solderless type is connected to the wire by special tools that deform the barrel of the terminal and exert pressure on the wire to form a strong mechanical bond and electrical connection. Solderless-type terminals gradually have replaced solder-type terminals in military equipment.

b. Solderless Terminals (Fig. 17-36). Solderless terminals come in a variety of designs. Some of the more common recommended terminals are the ring-tongue, rectangular-tongue, and flag types. One of the major sources of trouble when a terminal is connected to a wire has always been the breakage of the wire near its junction with the terminal. Wire failures have been decreased by adding a sleeve to the basic terminal. The inside diameter of the sleeve is slightly larger than the outside diameter of the wire insulation. In the crimping operation, when the

TA233645

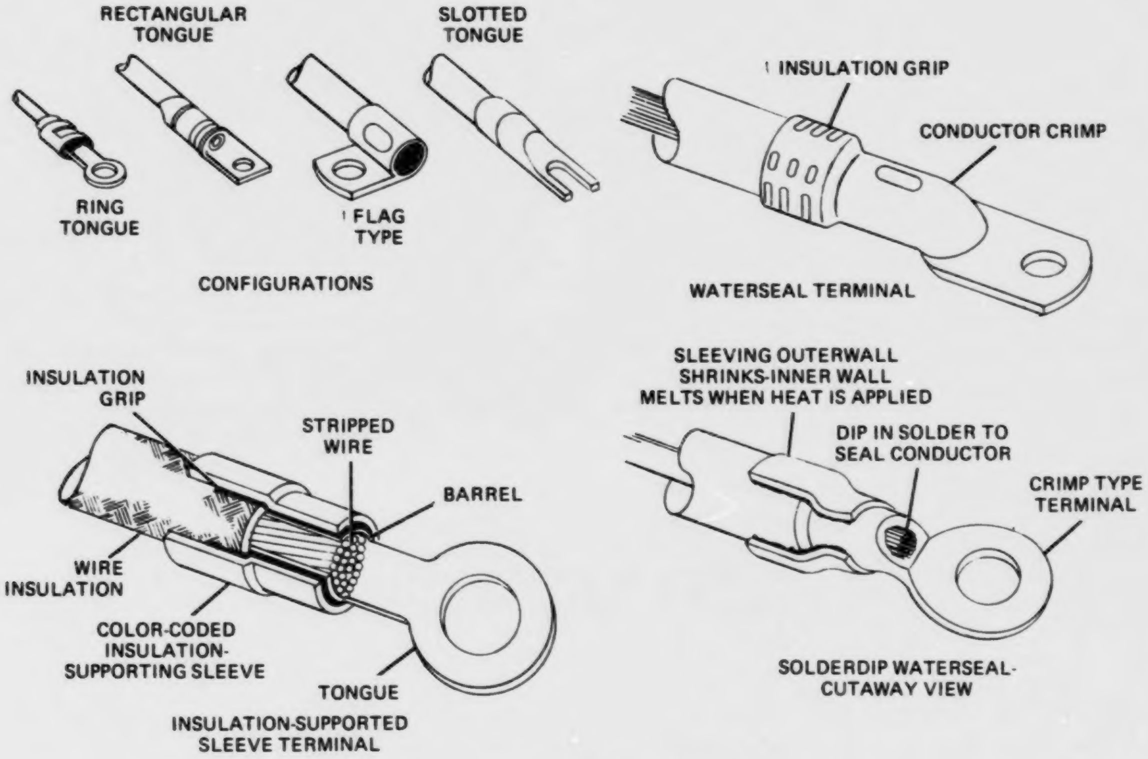

RECTANGULAR TONGUE
SLOTTED TONGUE
RING TONGUE
FLAG TYPE
CONFIGURATIONS
INSULATION GRIP
CONDUCTOR CRIMP
WATERSEAL TERMINAL
INSULATION GRIP
STRIPPED WIRE
BARREL
WIRE INSULATION
COLOR-CODED INSULATION-SUPPORTING SLEEVE
TONGUE
INSULATION-SUPPORTED SLEEVE TERMINAL
SLEEVING OUTERWALL SHRINKS-INNER WALL MELTS WHEN HEAT IS APPLIED
DIP IN SOLDER TO SEAL CONDUCTOR
CRIMP TYPE TERMINAL
SOLDERDIP WATERSEAL-CUTAWAY VIEW

Figure 17-36. Electrical Terminals.

barrel is fastened to the end of the wire, the insulation-supporting sleeve is fastened around the insulation. This additional support prevents excessive bending of the wire at the point where it enters the barrel of the terminal, and also prevents fraying of the insulation or braid that is over the wire. A special water seal terminal, designed to fit MIL-C-13486 cable and grip the insulation to prevent water from reaching the conductor, also is provided. This terminal should be used wherever MIL-C-13486 interconnecting wire is terminated in an area subject to bilge water, road splash, or corrosive spills. If water seal terminals are not used in such circumstances, the stranded conductor will absorb moisture, and rapid corrosion of the individual strands will occur.

c. Solder-Type Terminals (Fig. 17-36). Solder-type terminals come in most of the configurations. Although they are considered to make more positive, permanent connections, they are not used as widely as solderless connectors because of the difficulty involved with installing them.

17-25. Wire Connectors (Fig. 17-37).

a. General. Connectors have evolved to facilitate the coupling and uncoupling of electrical equipment for replacement or service. The typical connectors used on military vehicles permit the elements of a system to be fabricated and serviced as individual assemblies or components so that the final system configuration is built and maintained more easily. The interconnection generally is accomplished using multiconductor or single-conductor cable assemblies or wiring harnesses, which permit convenient placement of the system components. Connectors and receptacles also are attached directly to individual components to permit the easy removal of items that are connected to mating parts without the use of interconnecting cables (circuit boards and relays). A compatible connection system consists of a plug assembly, a mating receptacle assembly, and the wires or cables leading to them. Connector assemblies exist in a variety of configurations, each of which is intended for a particular environmental and/or mounting condition.

TA233646

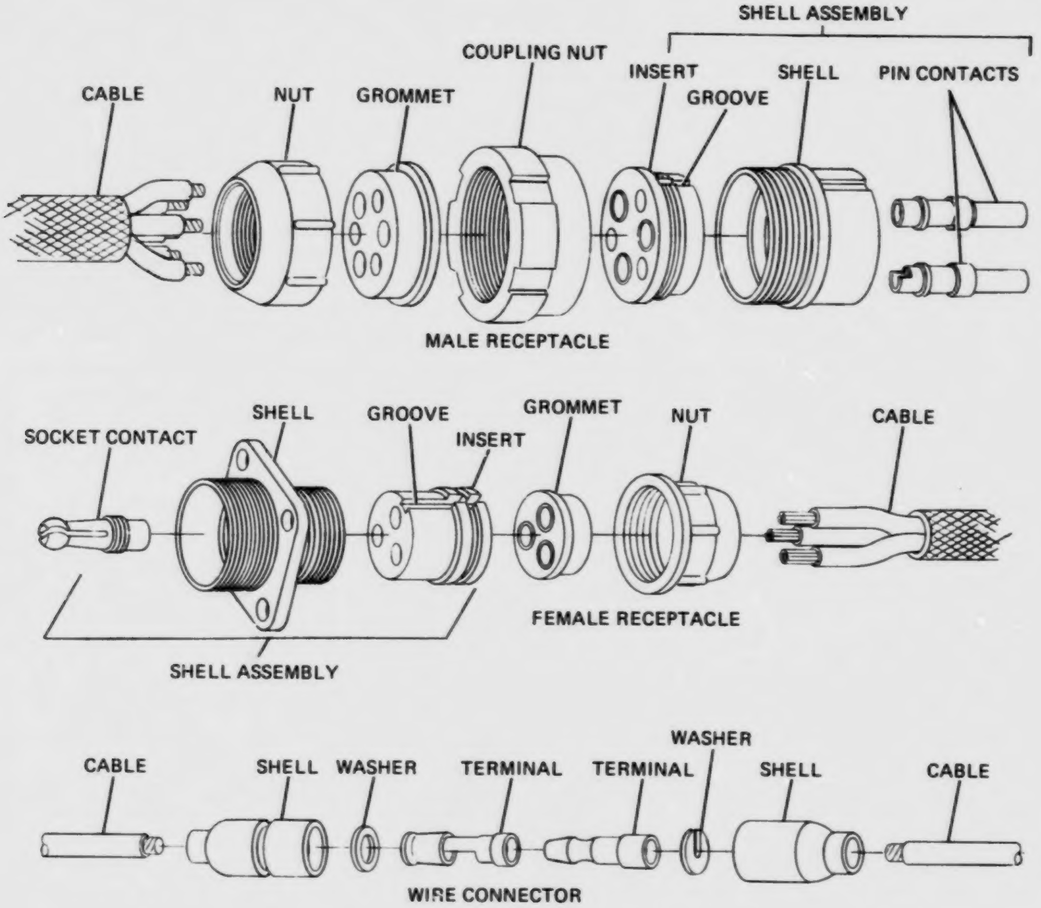

SHELL ASSEMBLY
COUPLING NUT
INSERT
SHELL
PIN CONTACTS
CABLE
NUT
GROMMET
GROOVE
MALE RECEPTACLE
SHELL
GROOVE
GROMMET
NUT
CABLE
SOCKET CONTACT
INSERT
FEMALE RECEPTACLE
SHELL ASSEMBLY
WASHER
CABLE
SHELL
WASHER
TERMINAL
TERMINAL
SHELL
CABLE
WIRE CONNECTOR

Figure 17-37. Wire Receptacles and Connectors.

b. Types. Plugs and receptacles are available with either pin- or socket-type contacts, that is, with either male or female contacts. The placement of one in preference to the other is based on a general rule prescribing that sockets (female) are used on the power side of a connection. This arrangement is intended to prevent accidental shorting of the power side of the connection, which could injure personnel or damage equipment. Connectors are designed specifically for high- or low-voltage applications. The various connector receptacles that are available for vehicle usage are classified as in-line or cable, box, wall, or bulkhead types.

(1) The in-line type has no means of supporting itself, is used on a cable end, and is joined to a mating element that also is cable connected. These in-line receptacles permit the interconnection of power distribution systems using two or more cable or harness assemblies to facilitate maintenance.

(2) The difference between box- and wall-mounted receptacles is related to the environmental protection of the conductor connections. The box-mounted style has exposed conductor connections, and is intended to be mounted on a box or component that is sealed and thereby provides the conductor connections with protection from the environment. A wall-mounted receptacle is intended to be mounted on an exposed or unprotected enclosure; therefore, the connections to the conductors are sealed.

(3) The bulkhead receptacle is used to penetrate a panel while maintaining a seal between the compartments established by the panel. The unique feature of the bulkhead receptacle is that it allows the connection on both sides

TA233647

of the panel to be removed easily. This is a significant difference from box- or wall-mounted receptacles, which have only one easily removable connection.

(4) There is also a variety of connector plug assemblies used on vehicles, and the primary physical difference between them is the backshell configuration. This backshell is used to direct the connecting wire or cable either axially or in angles up to 90 degrees from the axis of the connector, as well as to provide a water seal and strain relief for the cable or wire.

c. Requirements.

(1) Electrical connectors must be capable of withstanding the effects of the military environment. Protection against damage due to temperature extremes, water, oil, and physical abuse is mandatory.

(2) It is good practice to provide one or more spare contacts in the connector pair more than the actual number required for the circuits to carry. Then, any increase in circuits necessitated by functions added later will not require the use of another connector. It is advisable to keep the number of contacts per connector down to a number that can be mated and separated without excessive force. Where a large number of circuits must be handled, it may be advisable to use more than one connector pair. Every effort should be made to choose connectors that will allow signal and power leads to be bundled separately.

(3) The current to be passed through each contact must be determined. The contact size then can be established with a safety factor sufficient to provide safe operation under conditions of temporary overload. Another important safety factor is mechanical strength. In many applications, size 12 contacts are used, even though the current may be less than 100 mA because the mechanical strength of the size 12 contact is needed.

(4) Great care should be exercised in the selection of connectors to make certain that they will meet mechanical strains placed upon them in application. On vehicles, connector housings are used as personnel steps if they happen to be in the right location, and it is not an uncommon sight to see military equipment lifted or carried by one or more of its connectors even though connectors or thin housings are not intended for these purposes.

(5) The selected connector must have the means to prevent incorrect mating built into it. This may be effected through dissimilar-size guide pins, a nonsymmetrical arrangement of contact barriers, or the design of the connector shell housing. Contact pins should never be used for alinement or polarization.

CHAPTER 18

RADIO INTERFERENCE AND SUPPRESSION

Section I. INTERFERENCE

18-1. Automotive Radio. Although the supply and maintenance of radio equipment is a responsibility of the Signal Corps, its use by motor vehicle units for coordinating convoy movements in isolated areas must be considered. Transmitting and receiving equipment of this type depends upon the electrical system of the vehicle in which it is installed for its source of power.

a. Installation. Installation of these units varies in different types and makes of equipment. In general, units of radio equipment should be mounted on brackets, panels, or metal members that are attached to the body or frame by welding or riveting. All paints, lacquers, or primers should be removed from all mounting surfaces that come in direct contact with the equipment, and the surfaces should be tinned in order to ensure the best possible ground. The units should be located so that all switches or controls are within easy access of the operator. All flexible control cables should be free of sharp bends. So far as possible, installation or removal of this type of equipment should be done by specialists of the Signal Corps who are trained in this type of work.

b. Power Requirements. Radio units require from 4 to 5 amperes for receivers and 12 to 16 amperes for large units and transmitters. In many instances, it will be found necessary to equip the vehicle with a larger generator with a regulator device to supply the additional current. All power leads from the vehicle electrical system should be of sufficient size to meet the current requirements and should be equipped with fuses or other overload protection devices. All leads should be as short as possible. High-voltage direct current sometimes is necessary, in which case a motor generator is required.

c. Interference. Any sparks created by the operation of electrical equipment (such as spark plugs, circuit breakers, coils, generators, regulators, magnetos, or distributor assemblies), by loose or dirty connections, or by chafing of metal to metal, may cause interference with radio reception of nearby radio receivers. In addition, such sparks will disclose the location of the vehicle to sensitive electrical detectors. Because the units of the electrical equipment are connected by a wire or a series of wires, as in an automotive ignition system, the wiring acts as an antenna to transmit the interference created by the spark into the air. The captive effect of the wires and the spark-producing unit causes the radiated energy to affect a wide band of frequencies on a radio receiver, with pronounced effects on certain frequencies.

18-2. Ignition Noises.

a. Cause. When distributor breaker points are opened and closed by operation of the engine, the ignition coil produces a high-voltage current that flows across the gap in the spark plug to cause ignition. The sparks at the plugs and those at the breaker points cause violent surges of current to flow in all wires of the circuit (fig. 18-1). A magnetic field builds up around each wire and collapses with each make and break of the circuit. The rapidity with which these changes in the magnetic field are repeated is determined by the engine speed.

b. Recognition. The resultant noise in the receiver from breaker points, distributors, or spark plugs is recognized by clicking sounds that vary in rapidity and intensity with the speed of the engine.

18-3. Generator Noises.

a. Causes. With the generator in operation, there is some sparking between the brushes and commutator segments. Generators in good mechanical condition may exhibit some sparking, but this usually is not severe enough to cause radio interference. This type of sparking is increased by any of the mechanical defects listed below.

(1) Brushes do not fit commutator.

(2) Brushes are worn more than one-half their original length.

(3) Brush spring tension is incorrect.

(4) Oil or carbon particles collect around commutator.

(5) Commutator is worn out-of-round.

(6) Generator is loaded in excess of rated capacity.

(7) Commutator segments are burned or grooved.

(8) There is high insulation between segments of commutator.

b. Recognition. Sparking between the brushes and commutator segments may cause interference in nearby radio sets. This type of interference can be recognized by a roaring or whining noise that varies in pitch with the speed of the engine.

18-4. Body Noises.

a. Causes. Body noises are produced by loose screws and bolts that allow various parts of the body to chafe against each other. This chafing produces static discharges that are a source of interference to radio receivers. Static charges caused by friction and induced charges from wiring on the vehicles are collected by the vehicle body. These charges are retained by poorly grounded sections of the body until they build up to a sufficient value to jump to any well-grounded part of the vehicle. Each discharge causes a spark of sufficient intensity to create interference in a radio receiver. These effects are produced only when the vehicle is in motion, or for a very short period after the vehicle is stopped.

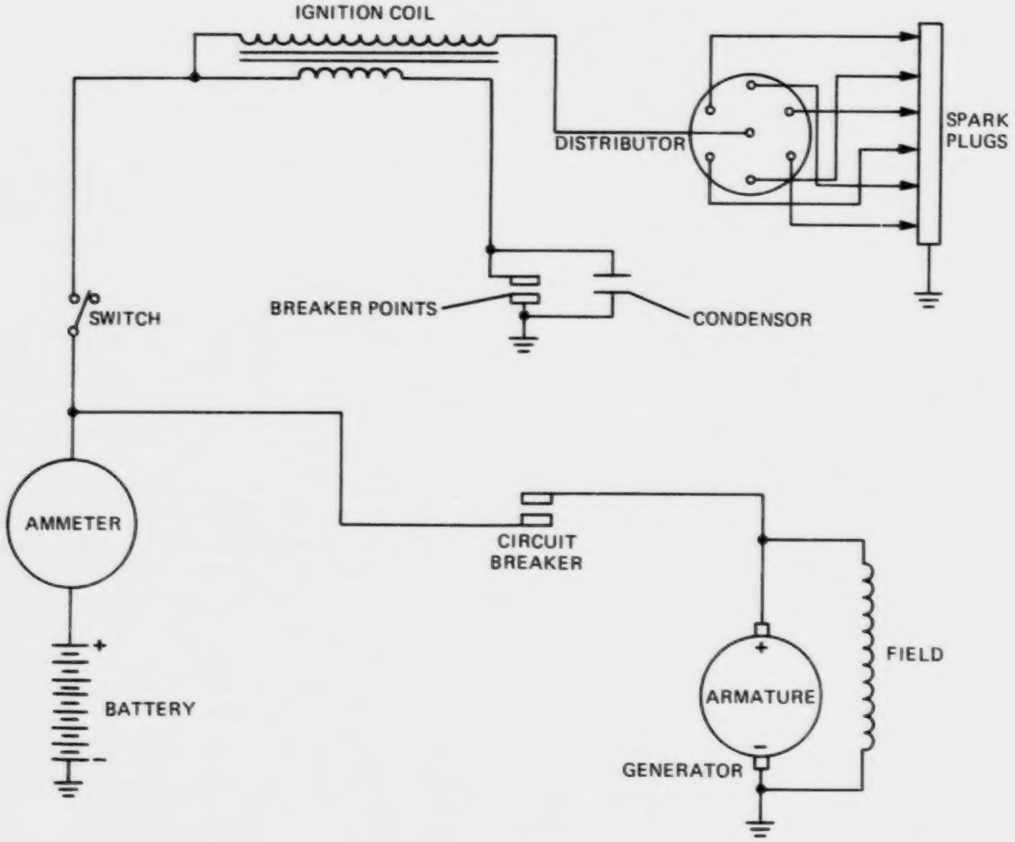


Figure 18-1. Typical Battery Ignition System. TA233648

313

b. Recognition. Looseness in the hood, brackets, and bolts can cause considerable noise in a receiver. This type of disturbance is intermittent, varies in value, and can be detected by a frying or snapping sound. It can be detected only when the vehicle is in motion; or, when moving the loose parts, it can be recognized by a scratching sound in a receiver.

Section II. SUPPRESSION

18-5. Description of Suppression Methods. Various methods are used to suppress radio interference caused by a vehicle. These methods include resistor-suppressors, capacitors, filters, bonding, and shielding.

Application of one of these methods usually is sufficient to suppress the interference from any one source adequately. However, in some instances, it may be necessary to use a combination of these methods to obtain the desired amount of suppression.

a. Resistor-Suppressors. A resistor-suppressor consists of a short carbon rod of high resistance, protected by a plastic cover. Resistor-suppresssors are connected in the high-tension wires at the spark plugs and distributor to reduce the intensity of surges and thus reduce interference from these sources. The resistance of the suppressors is high enough to control the surges but not high enough to affect the operation of the engine in any way. Some special-purpose spark plugs have a built-in resistor (para 15-3).

b. Capacitors. These are units of metal foils separated by paper insulation and protected by a metal case. The case is filled with an impregnating compound to keep the moisture out. A wire connected to one side of the capacitor is provided for connection to a circuit. The other side of the capacitor is connected internally to the case. Surges created in the wiring by sparks at the generator brushes, regulator, and gage contacts are not as strong as those produced by the high-tension ignition circuit because the voltage is low, but they are strong enough to cause interference in a radio set. Resistor-suppressors cannot be used in these circuits because their resistance would reduce the low-voltage current too much. However, capacitors, because of their inherent capacitance, may be used to dissipate these surges. They are attached to the circuit as near as possible to the point at which the spark occurs. The case of the capacitor is mounted on the metal frame of the unit causing interference, and the capacitor wire is connected to the terminal. A capacitor allows the interfering voltage to pass freely to ground (frame and body of vehicle), and at the same time prevents any loss of the useful direct current. Thus, the surges are conducted away from the wiring and cannot cause interference.

c. Filters. An assembly made of a closely wound coil of heavy wire and one or more capacitors mounted in a metal container is called a filter (fig. 18-2). The capacitors act in the same manner described in paragraph b above, and the coil of wire acts to block the interfering voltage from getting farther in the circuit. Filters are used in some generator, regulator, and low-tension ignition circuits.

d. Bonding (Fig. 18-3). This term is applied to the method of electrically connecting individual metal sections to each other and to the frame or hull of the vehicle. Such bonding is necessary to provide an easy path for grounding static charges. Bonding is accomplished by internal-external toothed lockwashers, and by bond straps. The better the connection between metal parts, the greater is the effect in preventing interfering waves from being thrown off to affect radio reception.

e. Shielding. This term is applied to the method of covering all wiring carrying interfering voltages or surges with a metal shield (fig. 18-2). Woven metal conduit is used where flexibility is required, while solid conduit is used elsewhere. Units causing interference, such as the spark plugs, ignition coil, distributor, and regulator, are enclosed in metal boxes. This shielding does not reduce the intensity of the interfering surges, but prevents their radiation. While such shielding is effective in preventing the radiation of interfering waves, filters and capacitors are necessary to eliminate any interfering surges that would otherwise travel on the wires and affect the radio set through the power supply. Such filters and condensers are enclosed in metal

381

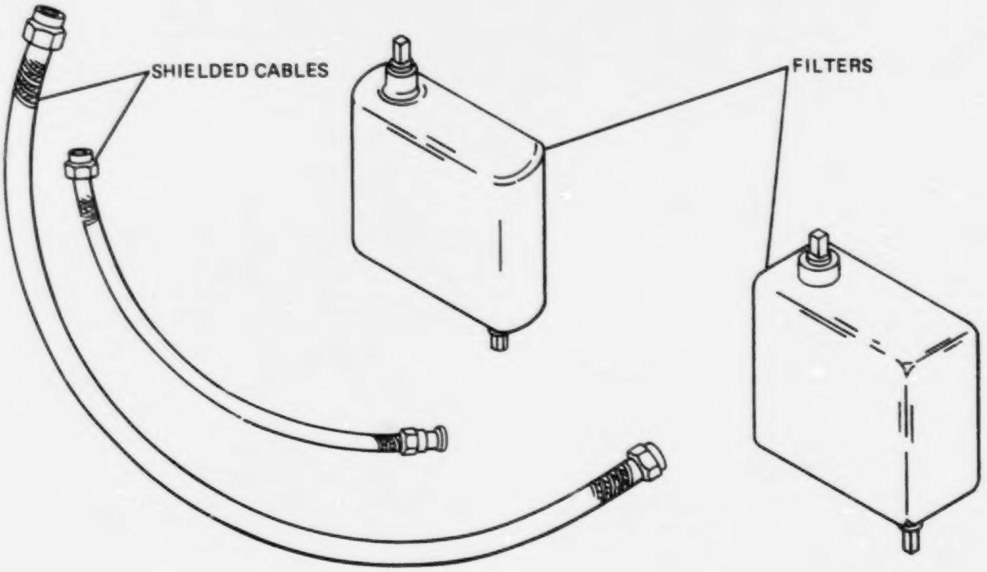


Figure 18-2. Radio Interference Suppression Filters and Cable Shielding.

shielding boxes provided with a means of attachment to the conduit and shielding containing the connecting wires.

18-6. Typical Applications of Suppression Systems to Vehicles.

a. Transport Vehicles – Ordinary Suppression System. The system found on most vehicles consists of the items described below.

(1) Resistor-suppressors are used in each high-tension lead from distributor to spark plugs. The suppressors are usually of a type that will slip over the terminal of the plug. The lead is screwed directly into the suppressor, thus locating the suppressor as close as possible to the spark gap in the plug.

(2) A resistor-suppresssor is used in the high-tension lead from distributor to coil. This suppressor is placed in the lead as close as possible to the distributor. Usually, it will be found approximately 1 or 2 inches away from the distributor.

(3) A filter is placed in the lead from the ignition coil to the ignition switch. This filter is mounted on the firewall, where the lead goes through to the switch. Thus, the exposed lead between the filter and firewall is kept as short as possible. In later production vehicles, this filter is replaced by a capacitor that usually is mounted on or near the coil, with its lead connected to the switch side of the ignition coil primary circuit.

(4) Filters are used in regulator circuits. One usually is connected between the battery terminal of the regulator and the ammeter, one is connected in the generator armature lead, and one sometimes is connected in the field lead between the generator and regulator. These filters are mounted on the firewall in such a position that the exposed leads leaving the filter are as short as possible. On certain vehicles, capacitors (usually 0.1-microfarad capacitance) may be found at these points, mounted on the firewall, with the leads connected to the battery and generator armature terminals. A 0.01-microfarad capacitor sometimes is applied with its lead connected to the field terminal of the regulator.

(5) A capacitor is mounted on the generator with its lead connected to the output terminal. Capacitors are used on certain lighting circuits, either mounted on the firewall or close to any junction point. The lead is connected to the circuit that may be carrying radio interference.

TA233649

385

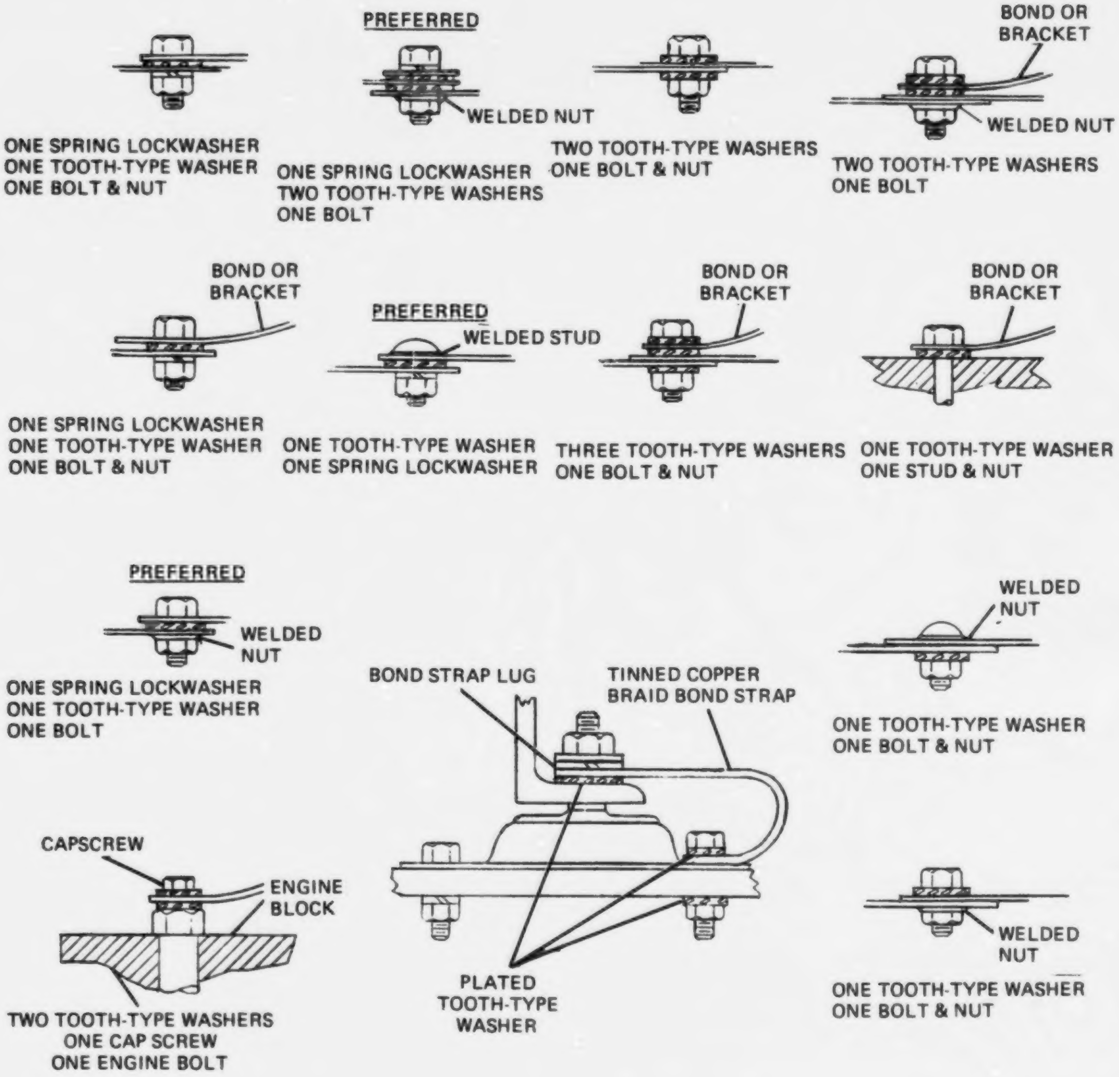

ONE SPRING LOCKWASHER
ONE TOOTH-TYPE WASHER
ONE BOLT & NUT
PREFERRED
WELDED NUT
ONE SPRING LOCKWASHER
TWO TOOTH-TYPE WASHERS
ONE BOLT
TWO TOOTH-TYPE WASHERS
ONE BOLT & NUT
BOND OR BRACKET
WELDED NUT
TWO TOOTH-TYPE WASHERS
ONE BOLT
BOND OR BRACKET
ONE SPRING LOCKWASHER
ONE TOOTH-TYPE WASHER
ONE BOLT & NUT
PREFERRED
WELDED STUD
ONE TOOTH-TYPE WASHER
ONE SPRING LOCKWASHER
BOND OR BRACKET
THREE TOOTH-TYPE WASHERS
ONE BOLT & NUT
BOND OR BRACKET
ONE TOOTH-TYPE WASHER
ONE STUD & NUT
PREFERRED
WELDED NUT
ONE SPRING LOCKWASHER
ONE TOOTH-TYPE WASHER
ONE BOLT
BOND STRAP LUG
TINNED COPPER BRAID BOND STRAP
PLATED TOOTH-TYPE WASHER
WELDED NUT
ONE TOOTH-TYPE WASHER
ONE BOLT & NUT
CAPSCREW
ENGINE BLOCK
TWO TOOTH-TYPE WASHERS
ONE CAP SCREW
ONE ENGINE BOLT
WELDED NUT
ONE TOOTH-TYPE WASHER
ONE BOLT & NUT

Figure 18-3. Examples of Bonding.

(6) Bonding straps usually will be found at the places described below. There may be others, also.

(a) From hood to firewall.

(b) From hood top panel to hood side panel.

(c) From overhead valve covers to firewall.

(d) From engine block to frame.

(e) From fenders and fender skirts to frame.

(f) From radiator brush guard to frame.

(7) Bonding by means of internal-external tooth lockwashers usually will be found at the places described below.

(a) Under head of side panel mounting screws.

(b) Hood holddown locks or latches.

TA233650

(c) At gage sending unit.

(d) Under head of radiator grille mounting screws.

(e) Under head of fender mounting screws.

(f) Under head of any bolt or screw securing a separate section of metal that will help form a shield in the vicinity of the engine compartment.

b. Transport Vehicles – Completely Shielded Suppression System. A few vehicles have a completely shielded system of suppressing, and in such cases, usually only one filter is used. It is mounted in a metal box close to the regulator (it may be on the cab side of the firewall). A capacitor will be found mounted on the generator, in a round metal shielding case. In most cases, the only bond is between the engine and the frame.

c. Tanks and Armored Cars. The resistor-suppressor system used on tanks with in-line engines, and on most armored cars, is basically the same as that used on transport vehicles described above. Usually, there will be fewer bonds and toothed lockwashers and more capacitors. Less bonds and washers are needed because of the heavy, bolted, or welded construction of the hull or body. Resistor-suppressors, filters, and capacitors are used in the same circuits as in the transport vehicles. More capacitors will be used to bypass the interfering surges from such accessories as auto-pulse fuel pump, electric gages, windshield wipers, traversing motors, auxiliary generators, and similiar items. The capacitors always are mounted close to the device causing interference, with the lead connected to the hot side of the supply line. The complete shielding system is used on most tanks having radial engines and on some armored cars.

In tanks, all wiring is enclosed in flexible metal conduit or solid metal conduit. Very little bonding is necessary with this system. In most cases, only the engine is bonded to the support or hull. Control devices consisting of metal rods or tubing extending from crew compartment to engine compartment may be bonded at the points they enter the crew compartment.

(1) Usually one filter is used, enclosed in a shielding box. It always is mounted close to the regulator and the battery.

(2) Capacitors are used on the electrical devices in the turret. They will be found at the brushes of the traversing motor, generator, and in the circuits of the stabilizer control switchbox.

In armored scout cars and gun motor carriages that have the completely shielded system, all high-tension, primary ignition, and charging circuit wiring is shielded with flexible metal conduit, which is grounded every 2 feet with clips and internal-external tooth washers. The distributor, ignition coil, and regulator are shielded.

(3) Filters may or may not be used. If one is used, it will be mounted close to the regulator on the firewall.

(4) A capacitor is mounted on the generator.

(5) Usually, the only bond is the one from engine to frame. Both sides of the engine are bonded.

PART FOUR

POWER TRAINS

CHAPTER 19

INTRODUCTION TO POWER TRAINS

Section I. PURPOSE

19-1. Providing Power to Propel Vehicle. One important function of the power train is to transmit the power of the engine to the wheels. In a simple situation, a set of gears or a chain could perform this task, but automotive vehicles usually are not designed for such simple operating conditions. They are designed to have great pulling power, move at high speeds, travel in reverse as well as forward, and operate on rough ground as well as on smooth roads. To meet these widely varying demands, a number of units have been added. These include clutches, transmissions, auxiliary transmissions, transfer cases, propeller shafts, universal joints, final drives, differentials, live axles, devices for resisting drive torques and thrust, and the bearings used therein.

19-2. Providing Power to Operate Accessories (Power Takeoff). The power train also is designed to direct power to the accessories. These branches from the main flow of power are known as power takeoffs. They may be connected to the transmission, auxiliary transmission, or transfer case. The simplest type of transmission power takeoff is the single-gear, single-speed type shown in figure 19-1. This unit is bolted over an opening provided for that purpose at the side of the transmission case. This opening is closed by a cover plate when no power takeoff is used. The opening in the transmission case and the power takeoff gear meshes with a gear on the transmission countershaft. As shown in figure 19-1, the gear slides on the splined main shaft, off which the power is taken. The shifter shaft, controlled by a lever in the driver's cab, slides the gear in and out of mesh with the countershaft gear. Because it is driven by the countershaft, the power takeoff shaft rotates in the same direction as the engine crankshaft.

Transmission power takeoffs are available in several different designs: a single-speed, two-gear model in which the rotation of the power takeoff shaft is opposite to that of the engine; a model having a single speed forward and reverse; and a model having two speeds forward and one reverse. Several different mountings also are available.

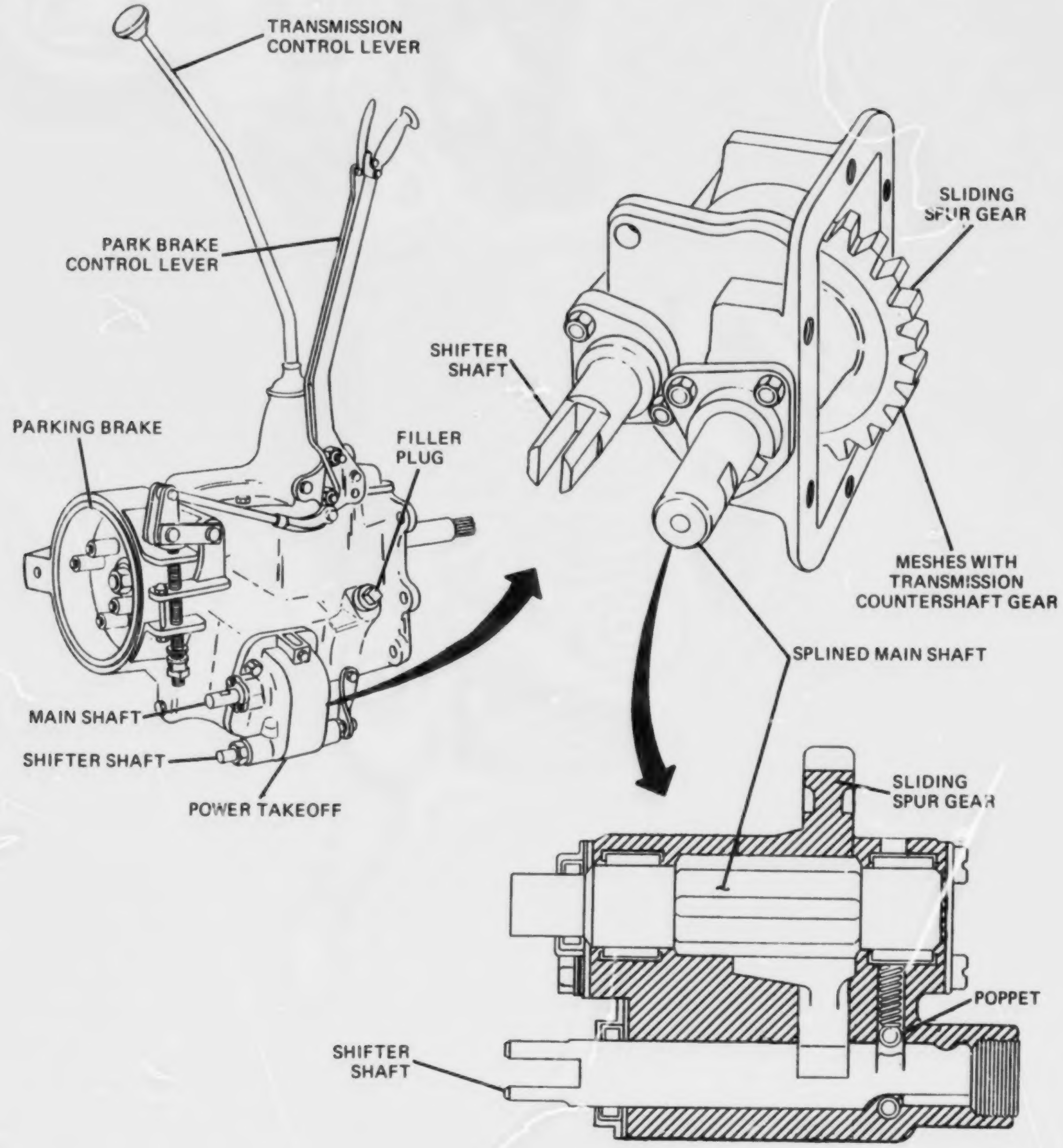
The same types of power takeoffs also are applied to auxiliary transmissions. Figure 19-2 shows a winch driven off of an auxiliary transmission.

Power sometimes is taken off a transfer case. The transfer case drive shaft, which is connected to the transmission, extends through the case, and the power takeoff shaft is engaged to it by a dog clutch. This transfer case has two speeds and a neutral position. It is necessary to put the transfer case sliding gear in the neutral position if the vehicle is to be stationary while the power takeoff is in use. If the power takeoff is needed while the vehicle is in motion, the transfer case may be shifted either into high or low range. With this arrangement, the power takeoff will work on any speed of the transmission.

When the power takeoff clutch is engaged, the winch capstan operates; but the winch drum does not rotate until the winch clutch is engaged.

The several types of power takeoffs have been described as operating winches, but their uses for operating various kinds of hoists, pumps, and other auxiliary power-driven machinery are essentially the same.

388


TRANSMISSION CONTROL LEVER
PARK BRAKE CONTROL LEVER
PARKING BRAKE
FILLER PLUG
MAIN SHAFT
SHIFTER SHAFT
POWER TAKEOFF
SHIFTER SHAFT
SLIDING SPUR GEAR
MESHES WITH TRANSMISSION COUNTERSHAFT GEAR
SPLINED MAIN SHAFT
SLIDING SPUR GEAR
POPPET
SHIFTER SHAFT

SINGLE-SPEED, SINGLE-GEAR POWER TAKEOFF

Figure 19-1. Power Takeoff.

TA233651

389

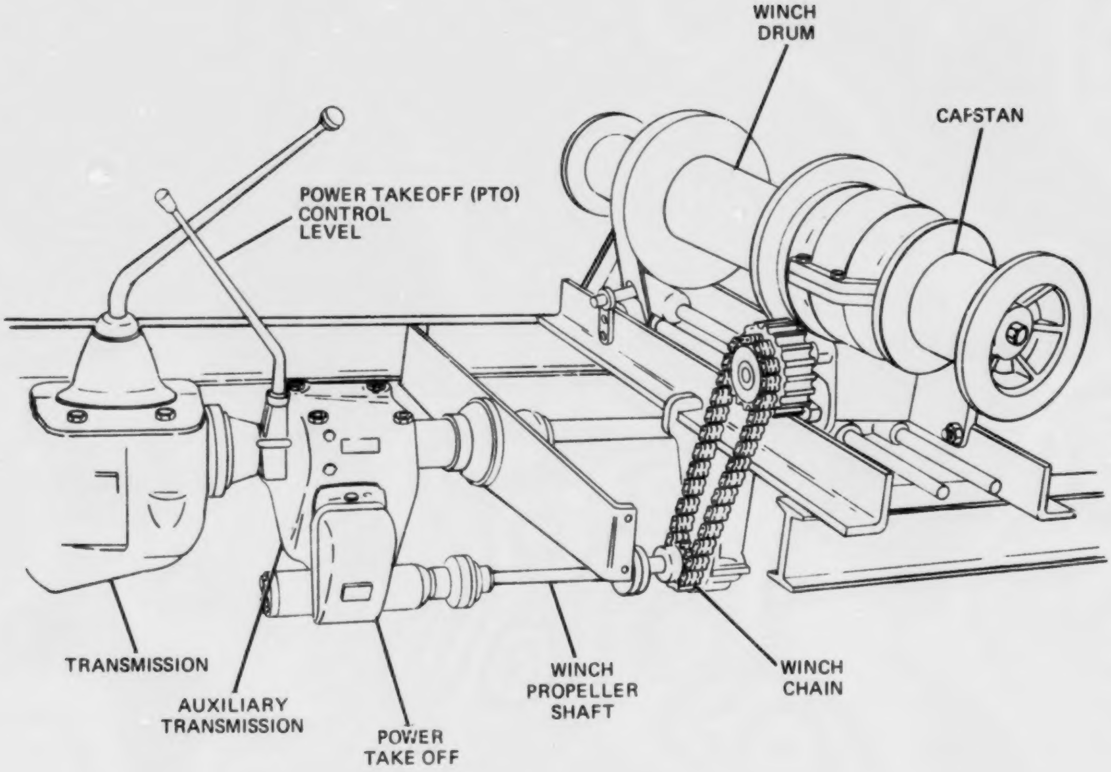


Figure 19-2. Power Takeoff Driving Winch.

Section II. GEARS

19-3. Principles of Gearing. Because gears play an important part in power trains, gear principles as well as various types of gears used in power trains will be discussed. Gears are used to transmit rotary motion from one shaft to another. Sometimes the shafts are parallel to each other, at other times they are at an angle. The gearing is selected to fit the application and provide the desired drive ratio (ratio of revolutions per minute) between the driving and driven shafts.

a. Torque Ratio. Torque has been defined as a twisting, or turning, effort. When one gear drives the other, it turns the other by the application of torque. The torque ratio between two meshing gears varies with the mechanical advantage, that is, with the gear ratio of the driving to the driven gear. When a small gear drives a larger gear, for example, the speed is reduced but the torque delivered by the larger gear is increased. Thus, when a 12-tooth gear drives a 24-tooth gear, torque is doubled; that is, the torque of the large gear is twice that of the small gear. On the other hand, when the larger gear drives the smaller gear, the torque is reduced while the speed is increased.

To start an automotive vehicle moving, a great deal of tractive effort or torque must be applied to the driving wheels or drive sprockets. This may be accomplished by using a series of gears, or a gear train, which greatly reduces the speed and thereby greatly increases the torque between the engine and driving wheel or sprocket. A common arrangement in passenger cars permits a gear reduction, in first (or low) gear, of 12:1 between the engine and rear wheels. This means the engine crankshaft must turn 12 times to turn the rear wheels once. This speed reduction results in a torque increase. Ignoring friction, the torque increase would be twelvefold. That is, if the torque at the crankshaft were 100 ft lb, then the torque at the rear axles would be 1,200 ft lb. In large trucks and heavy military vehicles, the

TA233652

torque increase (or torque multiplication) may be much greater than 12:1.

b. Mechanical Advantage. The use of a lever to move heavy objects is well known. When a box is too heavy to be lifted by hand, a crowbar or lever can be used to lift it, as shown in figure 19-3. With the lever placed as shown, only half as much force is required on the lever to raise the box. Suppose that a lifting force of 200 pounds is required to raise the end of the box. With the lever arranged as shown, only a 100-pound downward push is needed on the lever. The farther out on the lever the hand is put (away from the pivoting point, or fulcrum), the less downward push is required. But also, the farther the hand must move to raise the box. The mechanical advantage of the lever is the ratio between the two distances from the fulcrum. In the example shown, the mechanical advantage is 2:1.

c. Mechanical Advantage in Gears. A rough comparison between mechanical advantage in levers and mechanical advantage in gears can be made. Such a comparison is shown at the bottom of figure 19-3. One end of the lever moves twice as far as the other. When two gears are meshed and one gear has twice as many teeth as the other, the smaller gear will rotate twice for each revolution of the larger gear. In other words, the mechanical advantage between the two gears would be 1:2 when the larger gear drove the smaller gear. If the smaller gear drove the larger gear, the mechanical advantage would be 2:1 because the smaller gear would have to exert half the force for twice the distance.

d. Mechanical Efficiency. The mechanical efficiency of a system is dependent upon gear ratios and the amount of power that must be transmitted through the system. If a large resistance must be overcome, the torque multiplication also must be high. If this factor is not correct, the driving system can be overloaded. On the other hand, if a small resistance is to be overcome, the driving system might not be used to its fullest capabilities, therefore producing an inefficient system.

e. Internal and External Gears. Gears are basically of two types: internal and external. Internal gears are shaped cylindrically with teeth machined on the inside. External gears usually are circular with teeth around the outside of the gear. An example of both gears is shown in figure 19-4.

19-4. Types of Gears. There are many types and designs of gears and gear systems. Some of the most popular gears found in the automotive vehicle are discussed below.

a. Spur. Spur gears (fig. 19-5) are the most common type of gear. The teeth are machined perpendicular to the axis of rotation. Because these gears mesh only one tooth at a time, they are not capable of absorbing great amounts of torque. They generally are noisy during operation and are used to change direction and/or speed.

b. Helical. Helical gears (fig. 19-5) have teeth machined at an angle to their centerline of rotation. This characteristic enables the gear to engage more than one tooth at a time. This type of gear, therefore, is stronger and able to transmit more torque than spur gears. Because of the angle cut of the gear, two meshing gears tend to move apart during use. This reaction therefore requires the use of a thrust washer or tapered bearing when using helical gears. Helical gears

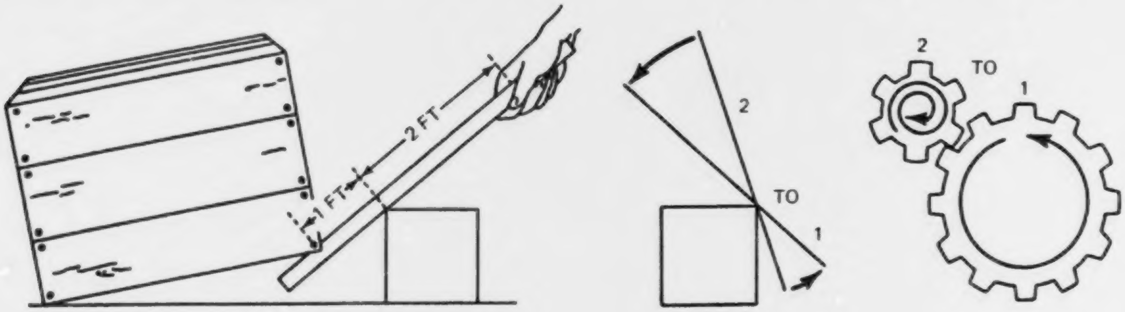


Figure 19-3. Mechanical Advantage.

TA233653

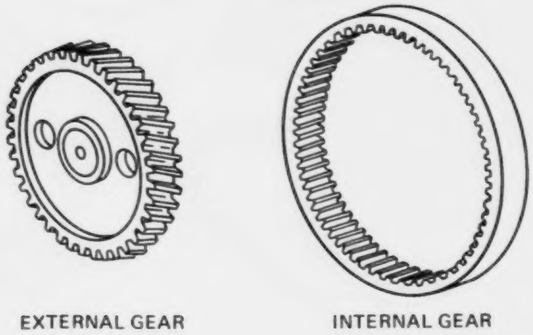

EXTERNAL GEAR
INTERNAL GEAR

Figure 19-4. Internal and External Gears.

generally operate quietly, even under heavy loads.

c. Herringbone. Herringbone gears (fig. 19-5) can be formed by attaching two helical gears in such a way that their teeth meet in a V-formation. The V-configuration cancels the side thrust created by each helical gearset. As herringbone gears mesh, more than one tooth is engaged at a time. This feature allows the gear to transmit large amounts of torque and operate quietly.

d. Bevel. Bevel gears (fig. 19-5) generally are used to change direction. Their teeth are machined at angles to the drive centerline to correspond with the angle of input and output shafts. Bevel gears, like spur gears, engage one

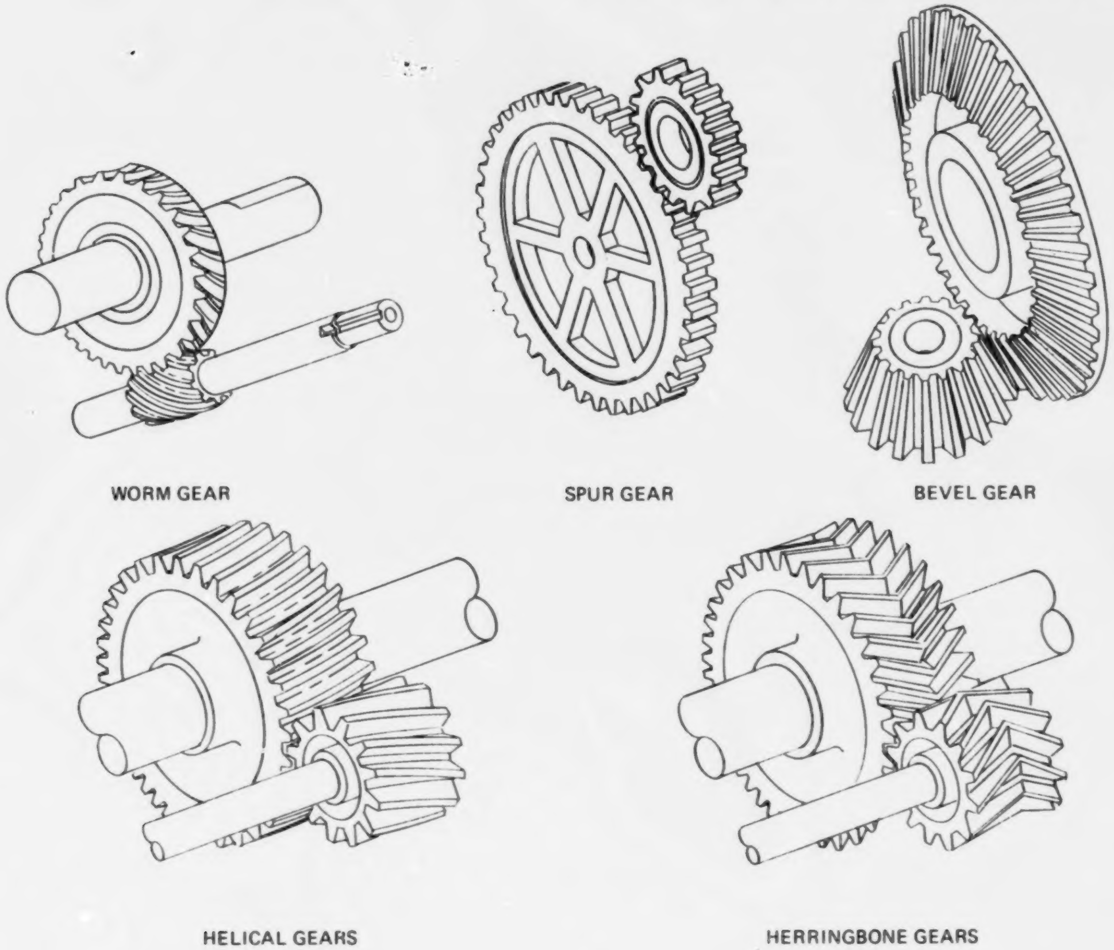

WORM GEAR
SPUR GEAR
BEVEL GEAR
HELICAL GEARS
HERRINGBONE GEARS

Figure 19-5. Types of Gears.

TA233654

392

tooth at a time; therefore, they are not able to transmit large amounts of torque and are noisy during operation.

e. Worm. Worm gears (fig. 19-5) basically are two different types of gears designed to mesh at right angles to each other. One gear is shaped similar to a helical gear, while the other is straight with teeth machined in a spiral form around the exterior of the shaft. Worm gears only can be driven by the rotating action of the long, spiral-shaped gear. The spiral-shaped gear also must have a means of absorbing thrust, because the rotating action of this gear causes it to move lengthwise during operation. This configuration produces great gear reduction and quiet operation.

19-5. Planetary Gear Systems. The planetary gear system (fig. 19-6) consists of three rotating members: the internal gear (or ring gear); the sun gear; and the planet pinion set, consisting of the planet pinions and the planet-pinion carrier, or cage. The reason the system is called a planetary gear system is that the planet gears rotate and at the same time revolve around the sun gear, just as the planets in our solar system rotate and also revolve around the sun. In the planetary gear system, the planet gears are assembled on shafts in a planet carrier or cage. Arrangements can be made to put power into any of the three rotating members and, at the same time, hold other members so that the gear ratio through the system can be increased or decreased. In addition, by the proper arrangement of turning and holding, the system can reverse rotation.

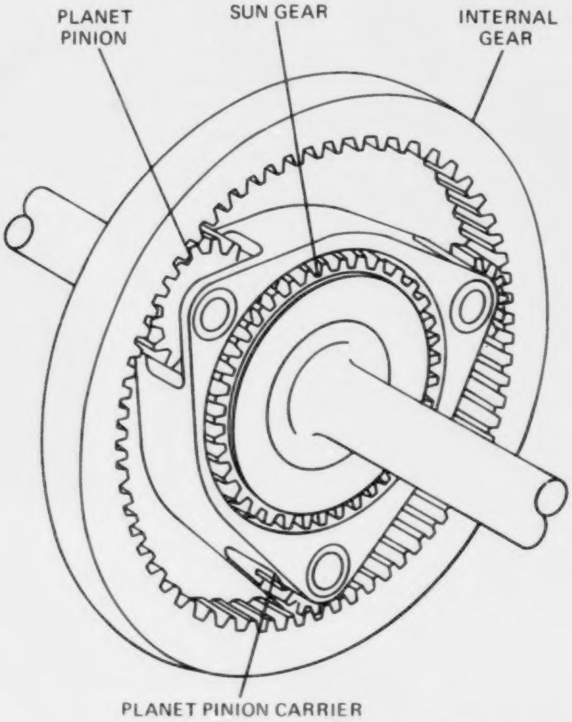


Figure 19-6. Planetary Gear System.

19-6. Six Basic Laws of Planetary Gearing. The chart in figure 19-7 shows the six conditions that can result in the planetary gear system from turning or holding the various members. For example, the column under Condition 1 shows that holding the sun gear while turning the pinion cage causes the internal gear to turn faster than the pinion cage. When the pinion cage is turned, the pinions must move around the sun gear because they are meshed with the sun gear. The pinions also are meshed with the internal gear, and, as they move around the sun gear and also rotate on their shafts, they force the internal gear to rotate. The rotation might be said to come from two sources: the rotation of the pinions on their shafts; and the rotary motion of the pinions as they are carried around by the pinion cage.

The other conditions listed in the chart (fig. 19-7) are not all used in automotive power trains, but they should be studied for a full understanding of the action of the planetary gear system. If the sun gear is held and the internal gear turned, then the pinion cage will turn, but more slowly than the internal gear. If the sun gear is turned and the internal gear held, the pinion cage will turn more slowly than the sun gear. On the other hand, if the internal gear is turned and the pinion cage held, the sun gear will turn faster than the internal gear, but in a reverse direction. The fifth condition results if the internal gear is held and the pinion cage turned; this causes the sun gear to turn faster than the pinion cage. The sixth condition is a common one because, by its use, reverse and gear reduction can be accomplished at the same time. The sun gear is turned while the pinion cage is held. This causes the internal gear to turn more slowly than the sun gear and in a reverse direction.

19-7. Sliding Surface Bearings (Friction). Essentially, a bearing is a support for a load. In automotive applications, bearings support moving parts, most of which are rotating parts. Not

TA233655

CONDITION	1	2	3	4	5	6
SUN GEAR	H	H	T	I,R	I	T
PINION CARRIER	T	L	L	H	T	H
INTERNAL GEAR	I	T	H	T	H	L,R

H - HOLD
T - TURN
R - REVERSE
I - INCREASE OF SPEED
L - REDUCTION OF SPEED

Figure 19-7. Laws of Planetary Gearing.

only do the bearings provide support, but they also serve to reduce the friction between the moving parts.

a. Sleeve-Type Bearings. These include bearings for rotating parts and for parts that merely slide over each other without turning. Most of the bearings of the mechanisms described in this section are for rotating parts. However, two examples of bearings for parts that do not rotate relative to each other are the shifter shafts in transmissions, which merely slide endwise in holes in the case, and the slip joints of propeller shafts.

The simplest type of sliding surface bearing applied to a rotating part is one in which an accurately finished shaft, or journal, rotates in an accurately finished hole without any bushing, the two being separated by an oil film. Such bearings may be used for differential pinions; the holes are in the rotating pinions, which turn on the stationary differential spider or cross pin.

Such bearings usually are known as plain bearings and are used only for low speeds or light duty or both.

Probably the next simplest plain bearing, also of the sliding-surface type, is the bushing that is replaceable when worn. A bushing is usually of bronze or similar relatively soft material and is pressed into a hole and reamed to fit, forming a lining in which a journal rotates. Plain bushings are suitable for radial loads only. Bronze bushings formerly were used to a considerable extent in automotive power transmission systems but have been superseded by antifriction bearings (ball, roller, or needle bearings). Bronze bushings are used extensively for piston pin bushings in internal combustion engines.

b. Thrust Washers. A thrust washer is a form of friction bearing designed to limit lateral movement. These washers generally are placed between moving parts or one moving part and a stationary member. They generally are not designed to absorb thrust constantly, as overheating can occur. Thrust washers generally are made of bronze or hardened steel.

19-8. Ball and Roller Bearings (Antifriction). These bearings are used throughout automotive power transmission systems. The usual locations of antifriction bearings in a truck chassis are shown in figure 19-8. They are known as antifriction bearings, because friction in them is eliminated because they depend upon rolling contact rather than sliding contacts. Ball bearings often are referred to as having point contact between balls and raceways; in the same sense, roller bearings are said to have line contact between rollers and races. These are merely descriptive terms, however, because the elastic deformation occurring under load results in substantial areas of contact in either type. The starting friction of ball and roller bearings is but slightly greater than their running friction, an important advantage in machinery that is required to start frequently under load. They also can sustain high overloads for short periods without failure. Ordinarily, a ball or roller bearing does not fail suddenly, but gives warning by a gradual decrease in smoothness of running; whereas, the plain bearing is subject to an accelerated type of failure that often results in

TA233656

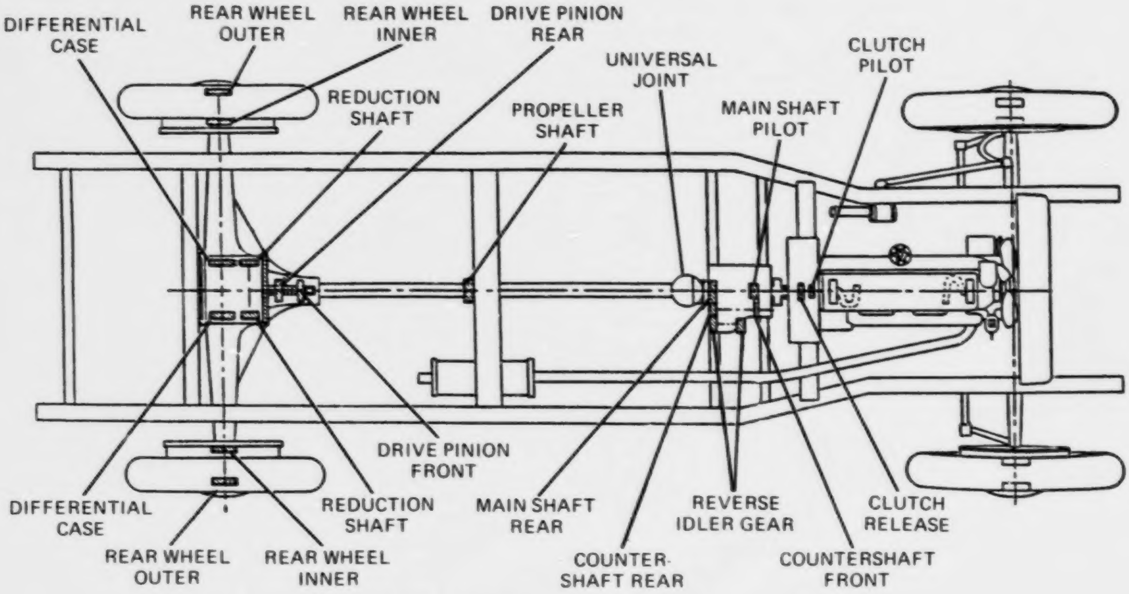

DIFFERENTIAL CASE
REAR WHEEL OUTER
REAR WHEEL INNER
DRIVE PINION REAR
UNIVERSAL JOINT
CLUTCH PILOT
REDUCTION SHAFT
PROPELLER SHAFT
MAIN SHAFT PILOT
DRIVE PINION FRONT
DIFFERENTIAL CASE
REDUCTION SHAFT
MAIN SHAFT REAR
REVERSE IDLER GEAR
CLUTCH RELEASE
REAR WHEEL OUTER
REAR WHEEL INNER
COUNTER-SHAFT REAR
COUNTERSHAFT FRONT

Figure 19-8. Typical Locations of Antifriction Bearings.

seizure, making it necessary to take the machine out of operation for immediate repairs.

a. Ball. A ball bearing consists of a grooved inner race and outer race with a number of balls spaced by a suitable cage or retainer between them. They are made with either a single or double row of balls. Ball bearings for various purposes differ considerably in the details of their constuction but are of three general types: radial, thrust, and angular. These terms are descriptive of the direction at which the load is applied to the bearing and the angle of contact between the balls and races designed to resist that load.

A single-row radial ball bearing is shown in A, figure 19-9. This bearing has radial contact between balls and races, and is designed primarily to resist radial loads, but also provides for lengthwise stability where moderate lengthwise displacement is permissible. It is suitable for usual combined radial and thrust loads and for high speeds.

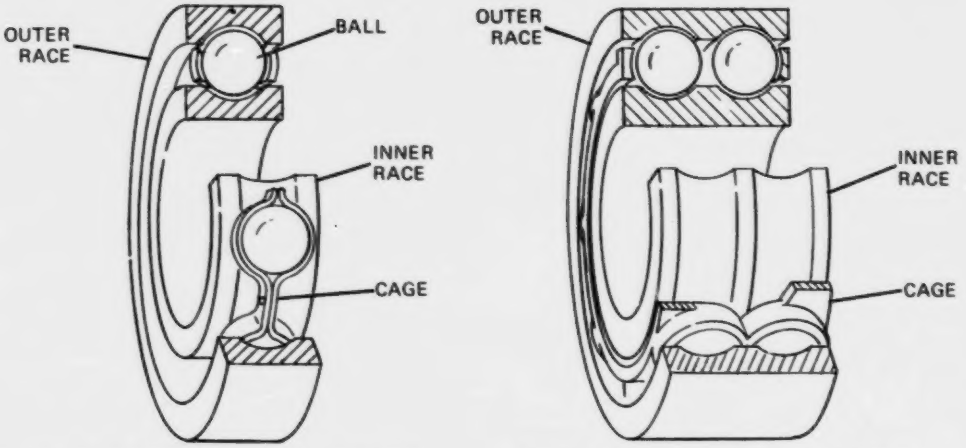
The double-row radial ball bearing shown in B, figure 19-9 is suitable for heavy combined radial and thrust loads, medium speed, and close control of endwise movement under reversing thrust.

Single-row, angular-contact ball bearings, such as those shown in C, figure 19-9, have substantial thrust capacity and provide rigid lengthwise support in one direction only. Also available are double-row, angular-contact bearings that have high combined load capacity with rigid lengthwise support in both directions.

Thrust bearings of the so-called flat type, such as those shown in D, figure 19-9, have a contact angle of 90 degrees, or a load line between ball and race that is parallel with the axis of the shaft. The small-bore race is secured to the shaft and the large-bore race is supported by the housing. Thrust in one direction presses the races and balls together; thrust in the other direction separates them. Therefore, this type is essentially a one-direction thrust bearing. Thrust in both directions necessitates the use of duplicate units or a bearing of the double-direction thrust type. Such bearings are suitable for limited speeds and minimum lengthwise displacement.

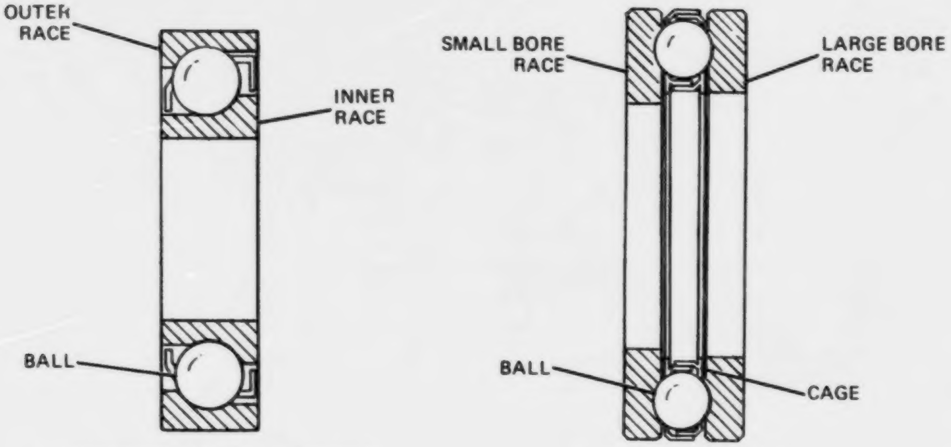
b. Roller. As in the case of ball bearings, the details of construction of roller bearings vary considerably for different applications. Like ball bearings, they are designed for radial, thrust, and combined loads. Roller bearings, which have greater contact area than ball bearings, are used for heavy-duty applications.

TA233657


OUTER RACE
BALL
INNER RACE
CAGE
OUTER RACE
INNER RACE
CAGE

A. SINGLE-ROW RADIAL BALL BEARING

B. DOUBLE-ROW RADIAL BALL BEARING


OUTER RACE
INNER RACE
BALL
SMALL BORE RACE
LARGE BORE RACE
BALL
CAGE

C. SINGLE-ROW ANGULAR-CONTACT BALL BEARING

D. FLAT-TYPE THRUST BALL BEARING

Figure 19-9. Typical Ball Bearings.

Cylindrical, or straight, roller bearings are bearings in which the outer races, rollers, and inner races are all cylindrical. Rollers usually are solid, as shown in figure 19-10, and the rollers are guided by flanges on one or both races. If both races are flanged, the bearing has some ability to resist end thrust, otherwise it is good for radial loads only. One manufacturer uses rollers formed by winding spiral strips of alloy steel into hollow cylinders, which then are heat treated and ground to size. This construction imparts some flexibility to the rollers and enables them to adjust themselves to small inaccuracies. Rollers wound right and left hand are assembled alternately in the bearing and held in proper alinement by a cage retainer. These bearings are made with

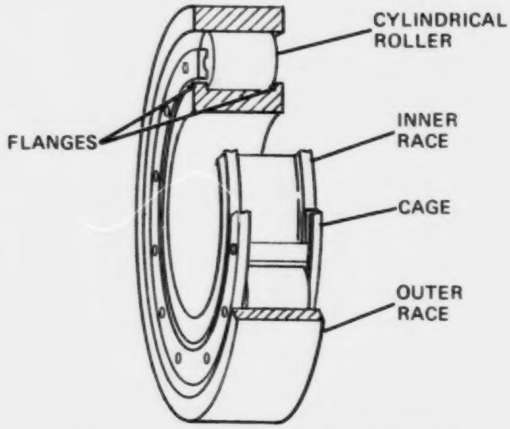

CYLINDRICAL ROLLER
FLANGES
INNER RACE
CAGE
OUTER RACE

Figure 19-10. Typical Roller Bearings.

TA233658

396

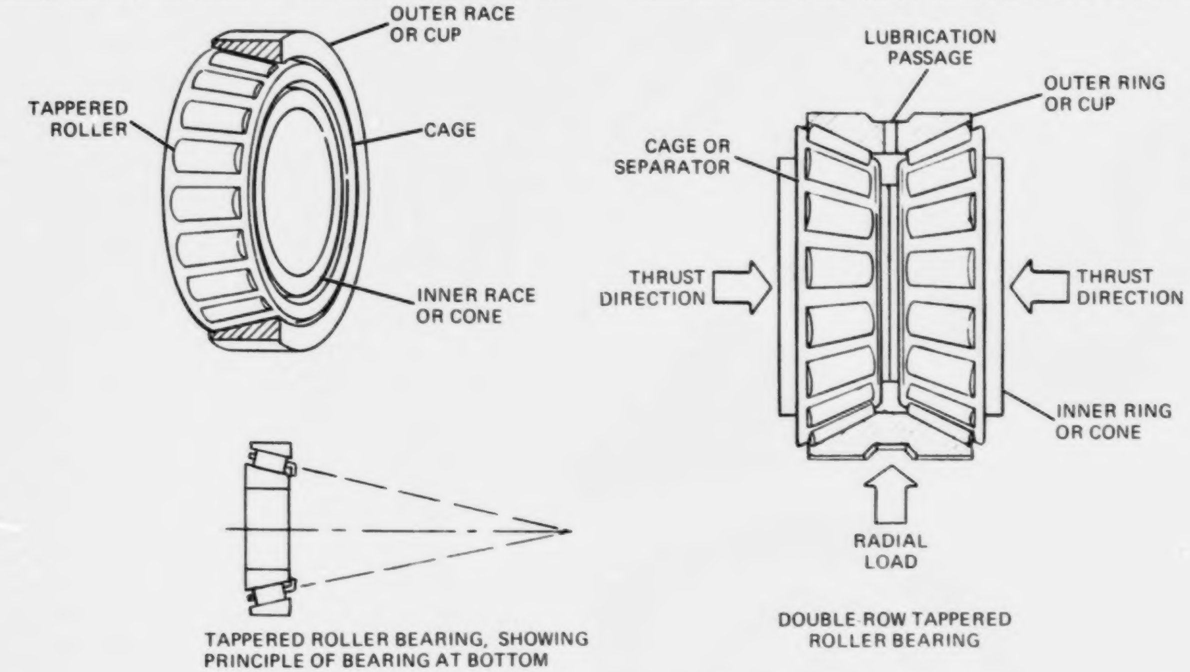
solid inner and outer races, with solid outer race and no inner race, and with a split outer race and no inner race.

c. Tapered Roller. Tapered roller bearings (fig. 19-11) are used extensively in automotive power transmission systems, especially for the more heavily loaded rotating members. The rolling members and raceways of the tapered roller bearings are constructed on the elements of a cone, so that lines that coincide with the contacting surfaces of rollers and races all meet at a common point on the axis of the bearing as shown at the bottom of figure 19-11. True rolling contact is thus obtained. The essential parts are an inner race or cone, an outer race or cup, tapered rollers, and a cage or roller retainer. These bearings are suitable for heavy duty, and can withstand radial loads and thrust loads in one direction or a combination of both. Such bearings also are available with double and quadruple rows of tapered rollers. Flat thrust bearings having tapered rollers, suitable for thrust loads only, also are available.

d. Needle Bearings. Needle bearings (fig. 19-12) (or quill bearings, as they sometimes are called) are cylindrical roller bearings in which the diameter of the roller is not over one-eighth the roller length. Separate outer and inner races may be used, or the inner race may be the shaft and the outer race integral with the housing. No spacing cage is used ordinarily; the rollers merely are constrained against endwise movement. Needle bearings are suitable for radial loads only. These bearings are used where a high load-carrying capacity is required in a small space. Needle bearings are used in many universal joints.

19-9. Bearing Lubrication. A basic requirement of ball and roller bearing lubrication is to protect the highly finished surfaces from corrosion. The supporting surfaces of the cage, or retainer, essentially are plain bearings and require an oil film. A small quantity of oil or grease will lubricate a bearing if it is distributed evenly. An excess quantity of lubricant is undesirable because it will cause the bearing to heat and will aggravate leakage from the bearing housing. Operating temperature is the controlling factor in selecting the proper grade of lubricant. Load, speed, and weather conditions directly affect this temperature, as does the particular type of bearing and the shaft enclosures.

The antifriction bearings in automotive power transmission systems are not lubricated as separate units but as parts of assemblies such as



TAPPERED ROLLER BEARING, SHOWING PRINCIPLE OF BEARING AT BOTTOM

DOUBLE-ROW TAPPERED ROLLER BEARING

Figure 19-11. Typical Tapered Roller Bearings.

TA233659

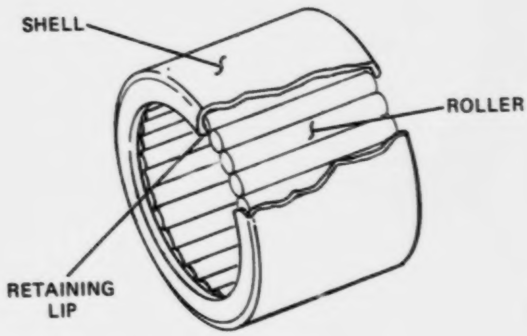


Figure 19-12. Typical Needle Bearings.

clutches, transmissions, universal joints, transfer cases, or rear axles. If these assemblies are lubricated in accordance with the specifications as set forth in the applicable technical manual, and with the lubricant prescribed for each, the bearing requirements will be satisfied.

19-10. Sealed Bearings. Some antifriction bearings are sealed at the factory and require no further lubrication. A shield (fig. 19-13) is used to contain the lubricant and prevent foreign matter from entering the bearing. These bearings generally are used when inherent lubrication is not available or a dirty operating environment must be overcome.

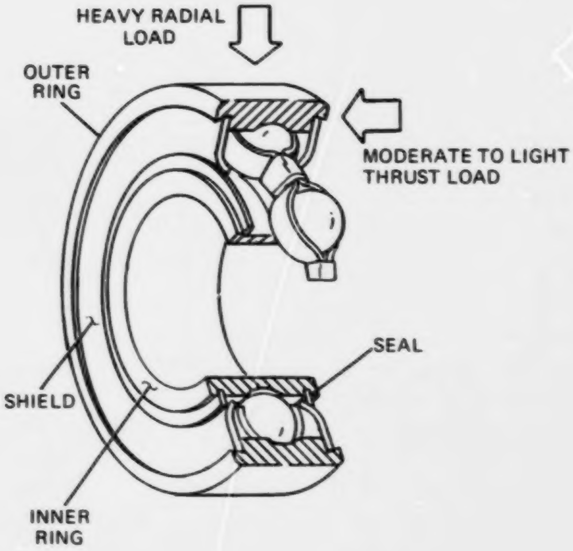


Figure 19-13. Typical Sealed Bearing.

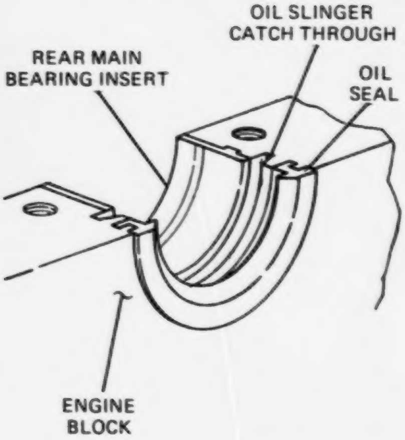
19-11. Oil Seals. Oil seals used in the automotive assembly are designed to prevent leakage between rotating and nonrotating members. Two basic types of oil seals are used on today's vehicles. Each is discussed below.

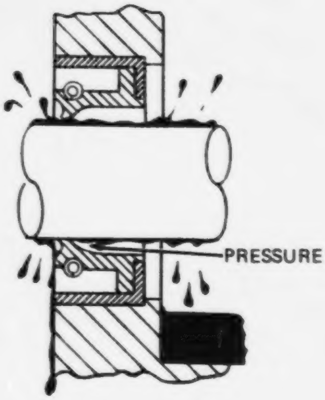
a. Synthetic Rubber Seals. The synthetic rubber oil seal (fig. 19-14) is the most common type of oil seal. It is composed of a metal case used to retain its shape and maintain rigidity. A rubber element is bonded to the case, providing the sealing lip or lips that rub against the rotating shaft. Different types of oil seal designs are illustrated in figure 19-14. A coil spring, sometimes called a garter spring, also is used to hold the rubber element around the shaft with a controlled amount of force. This allows the seal to conform to minor shaft runout. Some synthetic rubber seals fit into bores mounted around the shaft. This type is generally a split design and does not require a metal case or garter spring. Some oil seals rely on pressure to aid in sealing. Figure 19-14 illustrates the effects of pressure on lip seals. Internal pressure developed during operation forces the sealing lips tighter against the rotating shaft (fig. 19-14). This type of seal only will operate effectively against fluid pressure from one direction. Leather also is used as a lip seal. In this configuration, the seal inside diameter is smaller than the shaft (fig. 19-14). As the shaft is installed, the seal bows outward to form a lip seal.

b. Wick Seals (Fig. 19-15). The wick seal made of graphite-impregnated asbestos wicking sometimes is used to control oil leakage. This seal conforms to the recess in which it is installed. When using this type of seal, a knurled finish is used on the rotating shaft. The oil is contained between the knurls and seal, which rub together. As the shaft rotates, the oil is driven back by the propeller effect of the seal and knurl finish. An oil slinger sometimes is used with wick seals (fig. 19-15). The oil slinger is a raised washerlike area on the shaft. As oil meets the slinger, it is propelled outward by centrifugal force. A catch trough then is used to collect the oil and return it to the sump.

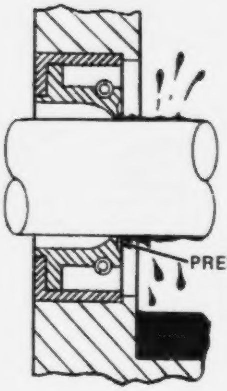
19-12. Gaskets (Fig. 19-16). Gaskets, otherwise known as static seals, are used to form pressure-tight joints between stationary members. They usually are made of a deformable material in the shape of a sheet or ring, which

TA233660

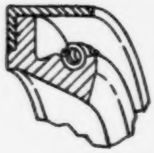

REAR MAIN BEARING INSERT
OIL SLINGER CATCH THROUGH
OIL SEAL
ENGINE BLOCK



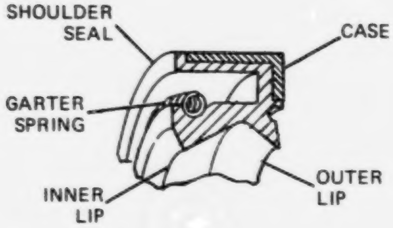
SEAL INSTALLED BACKWARDS. UP FACES AWAY FROM FLUID CAUSING FLUID TO FORCE SEAL LIP FROM SHAFT, CAUSING LEAKAGE.



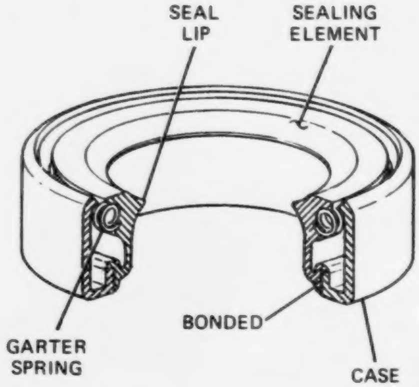
SEAL CORRECTLY INSTALLED WITH LIP FROM FACING FLUID. PRESSURE FORCES SEAL AGAINST SHAFT, PREVENTING A LEAK.

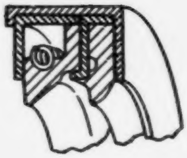


SINGLE LIP

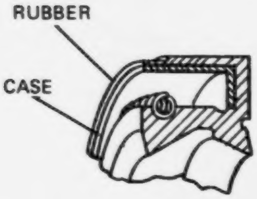

SHOULDER SEAL
CASE
GARTER SPRING
INNER LIP
OUTER LIP

DOUBLE LIP WITH RUBBER SHOULDER SEAL. INNER LIP CONTROLS OIL AND OUTER LIP KEEPS OUT DUST, WATER, ETC.


SEAL LIP
SEALING ELEMENT
GARTER SPRING
BONDED
CASE



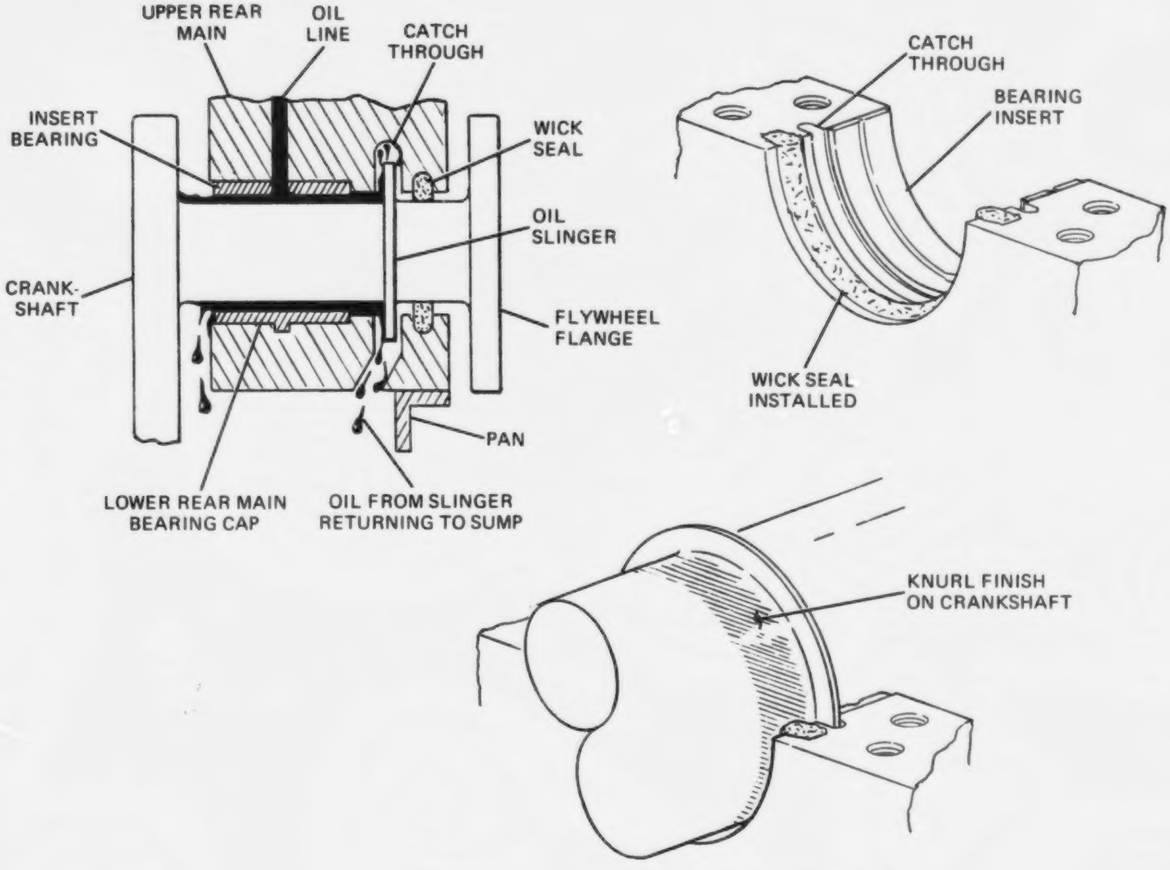
DOUBLE LIP, BOTH LIPS CONTROL OIL.


RUBBER
CASE

DOUBLE LIP WITH RUBBER OUTER COAT TO ASSIST OUTSIDE DIAMETER SEALING.

Figure 19-14. Synthetic Rubber Oil Seals.

TA233661


UPPER REAR MAIN
OIL LINE
CATCH THROUGH
INSERT BEARING
WICK SEAL
OIL SLINGER
CRANK-SHAFT
FLYWHEEL FLANGE
PAN
LOWER REAR MAIN BEARING CAP
OIL FROM SLINGER RETURNING TO SUMP
CATCH THROUGH
BEARING INSERT
WICK SEAL INSTALLED
KNURL FINISH ON CRANKSHAFT

KNURL FINISH ON CRANKSHAFT UNDER THE WICK-TYPE SEAL

Figure 19-15. Wick Seals.

conforms to irregularities in mating surfaces when compressed. Steel, aluminum, copper, asbestos, cork, synthetic rubber, paper, and felt are just a few of the materials that are used singly or in combination to produce leak-proof joints. The proper material used in gasket construction depends on the temperature, type of fluid to be contained, smoothness of mating parts, fastener tension, pressure of the substance to be confined, material used in construction of mating parts, and part clearance relationship.

Gaskets also can be formed by using a silicone sealant. This type usually is formed by applying sealant from a squeeze tube to the mating surfaces, and allowing it to dry, forming a sealed flexible joint. This type of seal is becoming more popular on modern vehicles.

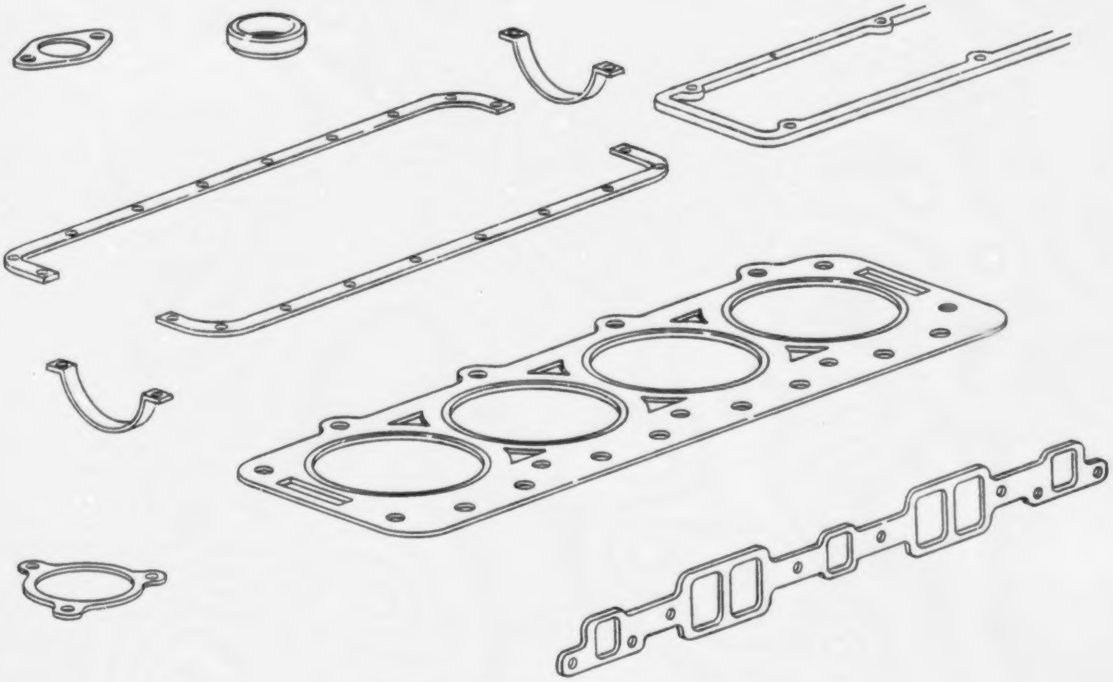


Figure 19-16. Typical Gaskets.

Section III. POWER TRAIN CONFIGURATIONS

19-13. Front-Wheel Drive (Fig. 19-17). Front-wheel drive vehicles deliver the driving force of the engine and transmission to the front wheels only. In this configuration, the rear wheels are designed to rotate freely. The front-wheel drive arrangement is more efficient than other configurations for the following two reasons:

a. Power generally is delivered in a straight line. The majority of front-wheel drive vehicles use a transversely mounted engine. This feature eliminates the power from being driven through different angles at the drive axles.

b. The front-wheel drive configuration has fewer moving parts. This helps reduce friction and increase engine life.

These features help make the front-wheel drive configuration one of the most popular designs on modern vehicles.

19-14. Rear-Wheel Drive. The rear-wheel drive configuration applies the driving force to the rear wheels. Front wheels are designed only to maneuver the vehicle. Rear-wheel drive vehicles can be powered by an engine mounted in front, middle, or rear (fig. 19-18). The front-mounted design is the most popular. This configuration (fig. 19-18) allows an engine to be mounted longitudinally with a clutch or torque converter and transmission mounted after the engine. Power then is delivered to the rear axle by the propeller shaft. Hypoid gears (para 29-9) generally are used in the rear axle to lower the drive line and allow the body to sit closer to the ground.

19-15. Four-Wheel Drive. A typical four-wheel drive is shown in figure 19-19. In this configuration, an engine is mounted in the front of the vehicle, followed by the clutch and transmission. Power then is delivered to the transfer case, where it is divided between the front and rear axles. The transfer case also is designed to move the front propeller shaft to the right, allowing for engine-to-drive train clearance. This configuration is very popular on many smaller heavy-duty vehicles.

TA233663

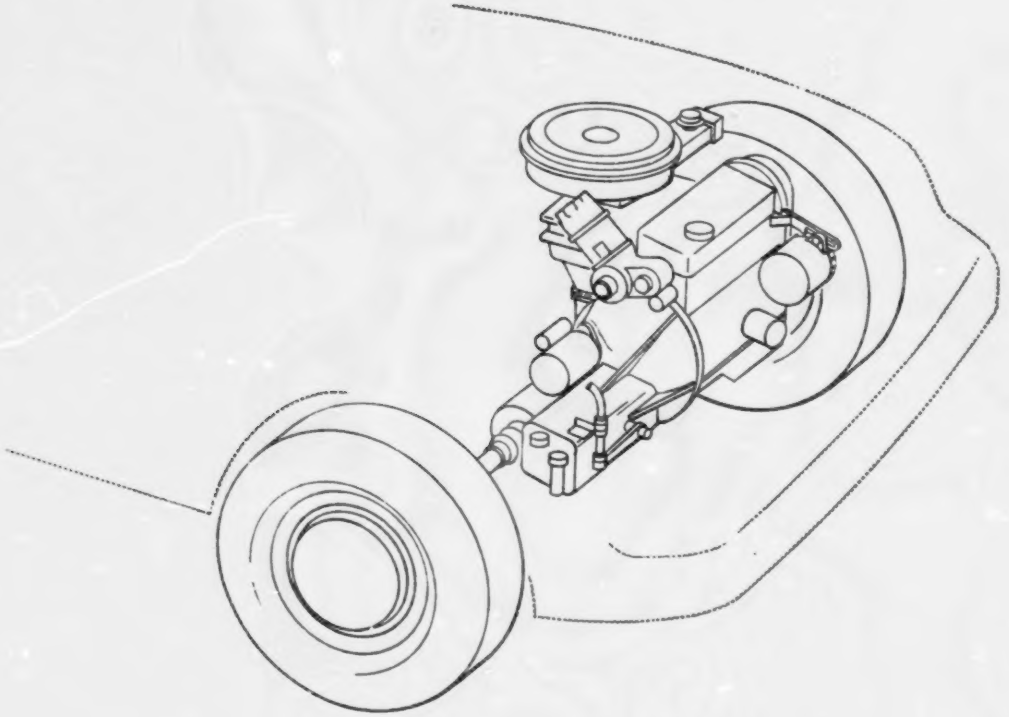
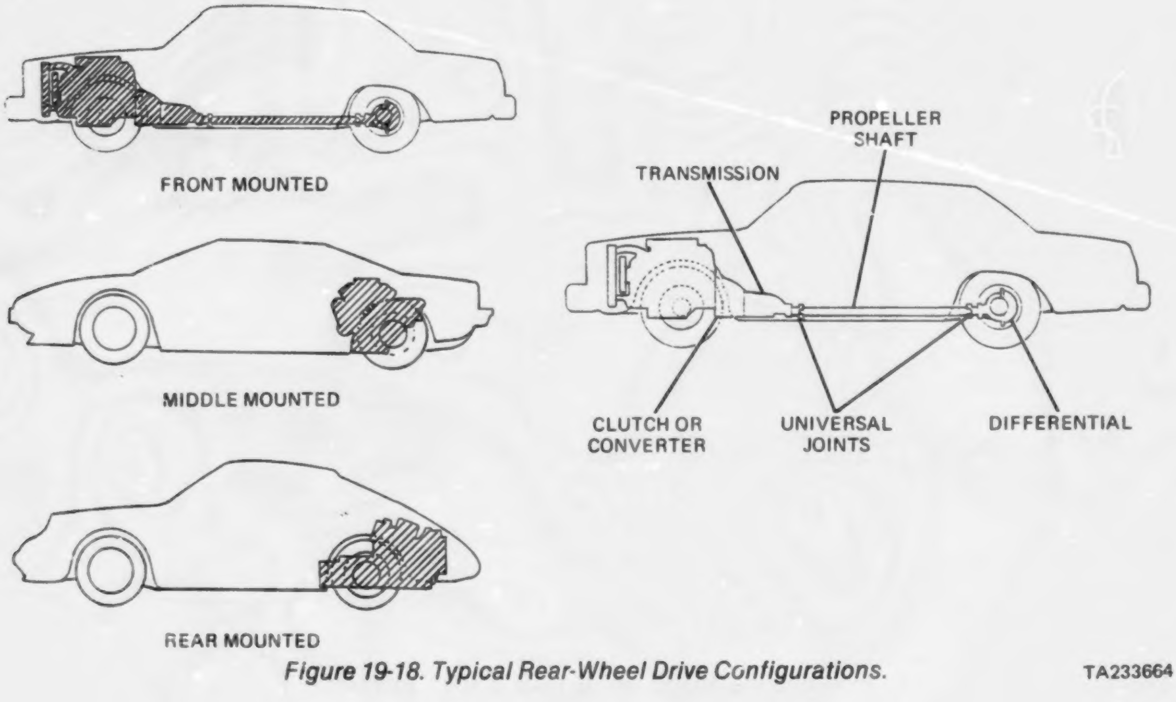


Figure 19-17. Typical Front-Wheel Drive Configuration.



FRONT MOUNTED

MIDDLE MOUNTED

REAR MOUNTED

PROPELLER SHAFT
TRANSMISSION
CLUTCH OR CONVERTER
UNIVERSAL JOINTS
DIFFERENTIAL

Figure 19-18. Typical Rear-Wheel Drive Configurations.

TA233664

402

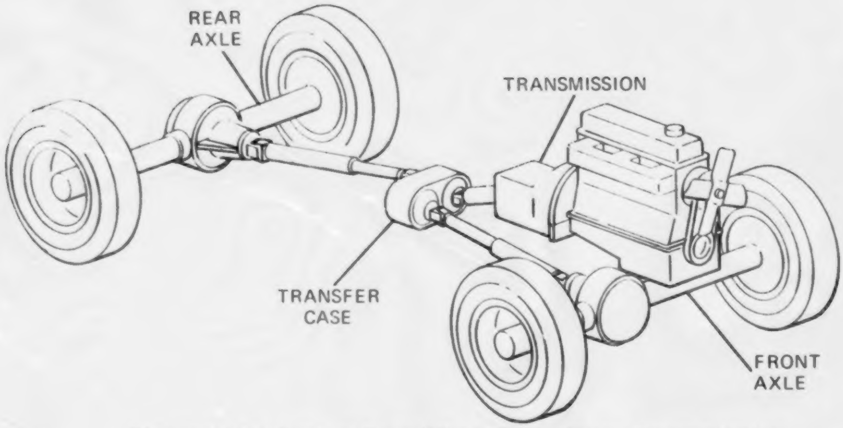


Figure 19-19. Typical Four-Wheel Drive Power Transmission.

19-16. Six-Wheel Drive. A six-wheeled vehicle, in which all six wheels drive, is shown in figure 19-20. This design is common on many larger military vehicles. Power is divided at the transfer case to all three axles. The differential and carrier on the forward rear axle is moved to the right to allow for rearward rear axle drive assemblies.

19-17. Eight-Wheel Drive. A vehicle in which all eight wheels drive is shown in figure 19-21. In this configuration, both front axles are designed to steer and drive. This allows the vehicle to maneuver on soft ground without sinking down.

19-18. Track Vehicle. The power trains in tracked vehicles perform the same function as in wheeled vehicles. However, they are designed for operating under more rugged conditions, and therefore are of more sturdy construction and, in general, provide for greater gear reduction.

Full-track vehicles are steered by varying the speed of one track in relation to the other, and this leads to the most important differences between wheeled and tracked vehicles. In some full-track vehicles, clutches are used in the final drive to each sprocket. By engaging and disengaging the clutches, the relative speed of the tracks can be controlled by the driver. This system is satisfactory for slow-speed vehicles.

In modern high-speed vehicles, steering is accomplished by means of a controlled differential. This differential employs a system of plane-

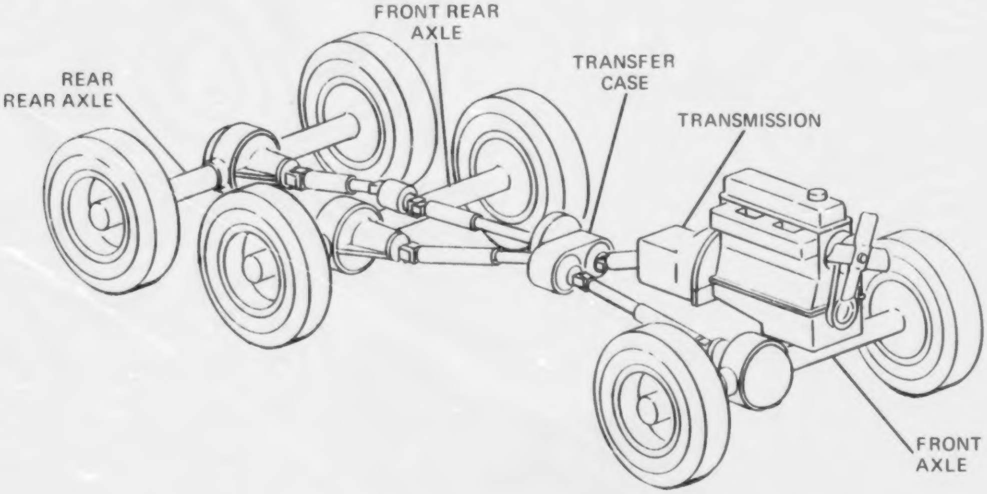


Figure 19-20. Typical Six-Wheel Drive Power Transmission.

TA233665

403

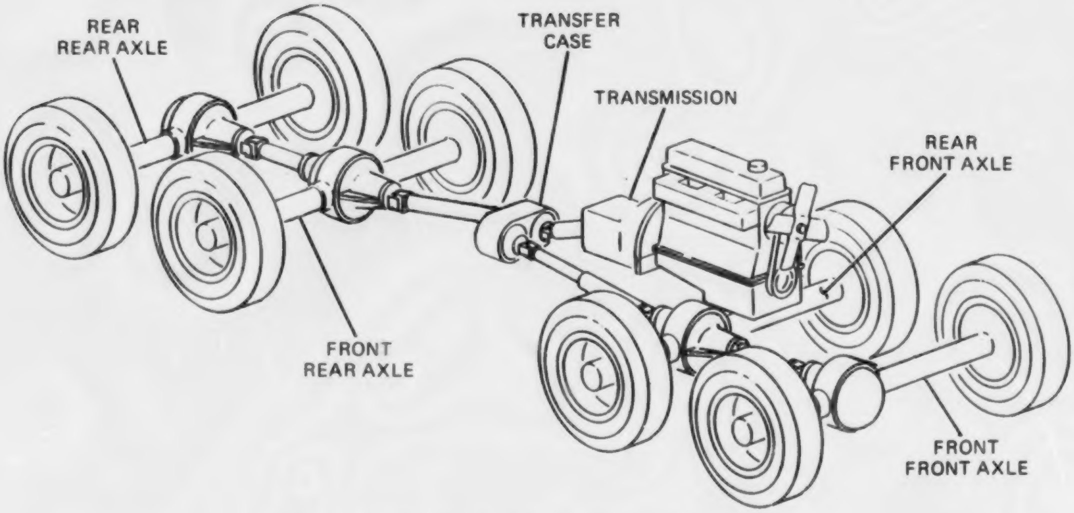

REAR
REAR AXLE
TRANSFER
CASE
TRANSMISSION
REAR
FRONT AXLE
FRONT
REAR AXLE
FRONT
FRONT AXLE

Figure 19-21. Typical Eight-Wheel Drive Vehicle.

tary gear trains, allowing power to be applied to both tracks at all times and still permitting the operator to regulate their relative speeds.

The cross-drive transmission (chapter 24) is one form of controlled differential used on late-type tanks; it utilizes a system of planetary gear trains as in other controlled differentials, but it also contains a torque converter.

TA233666

404

CHAPTER 20

HYDRAULIC PRINCIPLES

Section I. PRINCIPLES

20-1. Liquids Versus Gases (Fig. 20-1). One major factor that influences the compressibility of liquids and gases is their molecular bonding. Liquids have molecules moving freely around them, but not separating. Gases have molecules that are more active and tend to separate readily. Because both liquids and gases are compressed separately, their molecules act differently. Liquids have molecules that travel very short distances with almost no space between them. Attempting to compress the liquids yields almost no change in the space between molecules. Therefore, the volume also remains constant. This is the major reason why liquids are not compressed

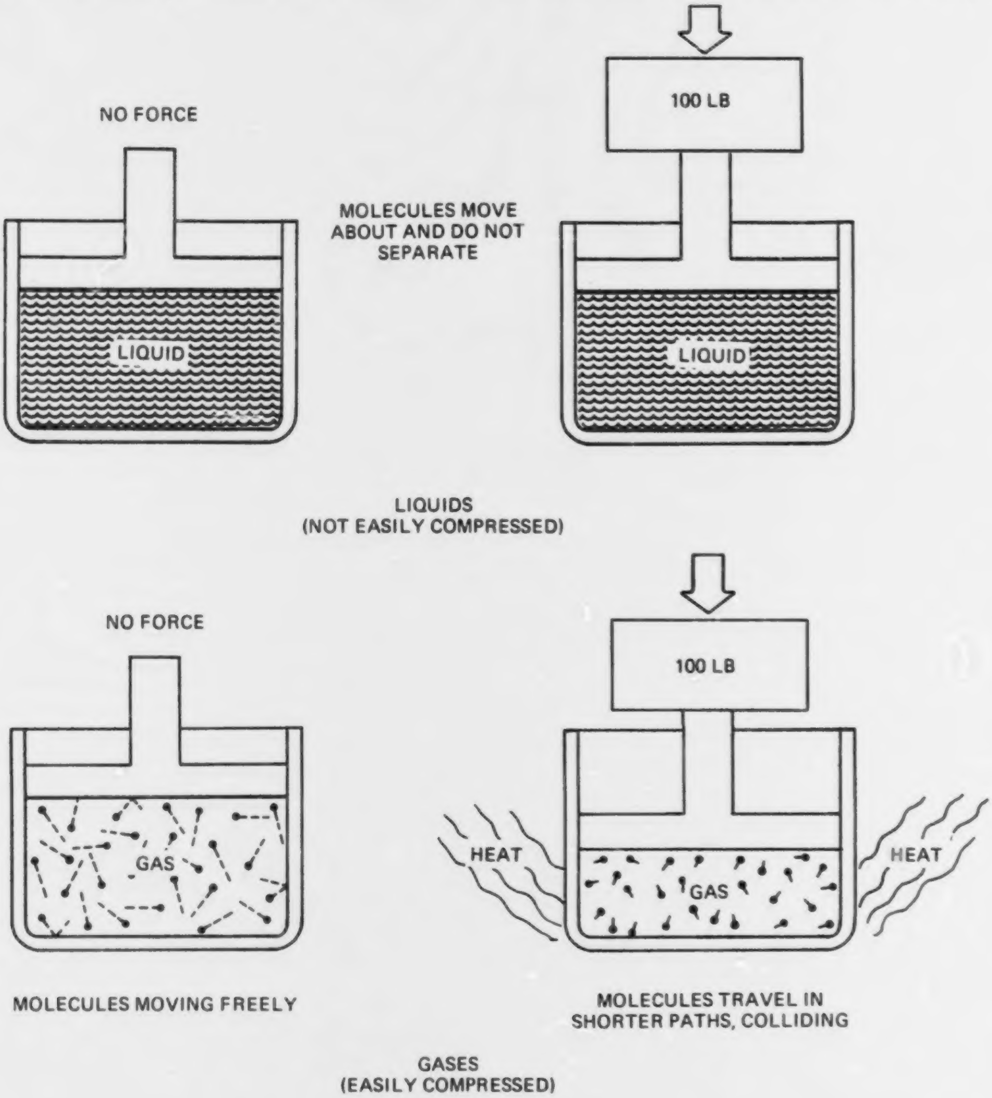

NO FORCE
100 LB
MOLECULES MOVE ABOUT AND DO NOT SEPARATE
LIQUID
LIQUID
LIQUIDS (NOT EASILY COMPRESSED)
NO FORCE
100 LB
HEAT
HEAT
GAS
GAS
MOLECULES MOVING FREELY
MOLECULES TRAVEL IN SHORTER PATHS, COLLIDING
GASES (EASILY COMPRESSED)

Figure 20-1. Compressibility of Gases and Liquids.

TA233667

readily. Gases, on the other hand, react differently when compressed. As a gas is compressed, the space between molecules is decreased, therefore allowing the volume to be decreased. As a result, the molecules are forced to travel shorter distances and interact more violently. This increased molecular interaction results in the generation of heat while compressing a gas.

20-2. Pascal's Law. Pascal's law states that in an enclosed system, fluid pressure developed by an external source acts evenly and in all directions without changing magnitude in the system. This principle is the basis for many systems in automotive vehicles. For example, brake, lubrication, and fuel systems are all dependent on Pascal's law. Figure 20-2 illustrates Pascal's law; note that the initial force of 50 psi (344.8 kPa) is distributed evenly throughout the system.

20-3. Mechanical Advantage in Hydraulic Systems. Hydraulic systems possess a definite amount of mechanical advantage. Comparisons can be made between a simple lever arrangement and a basic hydraulic system. Figure 20-3 illustrates how a lever and hydraulic system can be used to perform the same task. In this figure, both systems increase mechanical advantage, therefore making it easier to move the object. In A, figure 20-3, a long solid rod, with the fulcrum placed close to the object, is used to develop the mechanical advantage. In B, figure 20-3, a large-diameter piston is used to develop the force to move the object. In each system, certain factors must be forfeited to obtain this mechanical advantage. Each is listed below.

a. In the lever system, the rod must be pushed through a great arc to obtain a small movement with an increased force on the opposite end of the rod.

b. The hydraulic system requires the use of a large amount of fluid under the piston to raise the object slightly. This is illustrated in detail in paragraph 20-8.

These are two of the most important factors that must be considered when developing mechanical advantage.

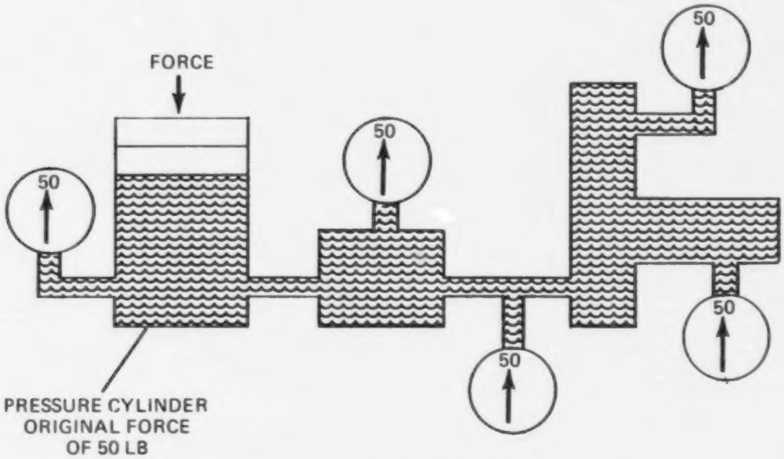
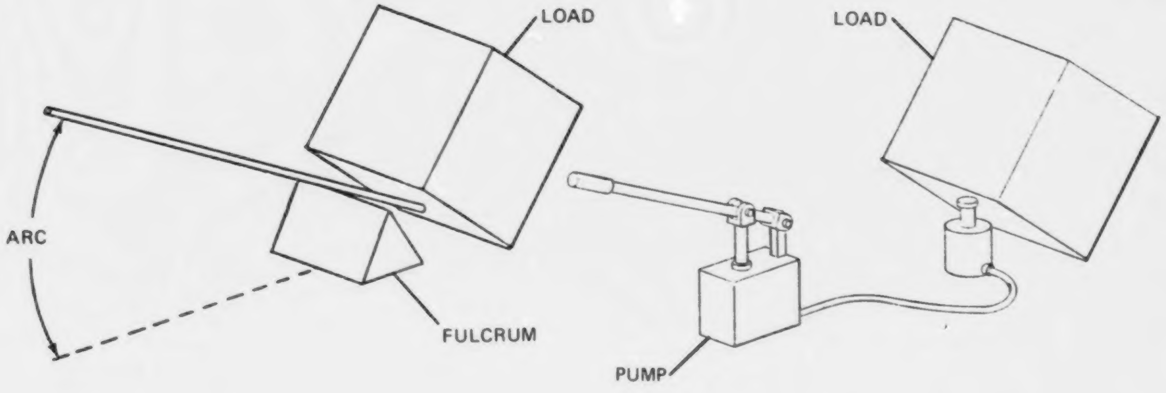


Figure 20-2. Pascal's Law.

TA233668

406

BEST COPY AVAILABLE



A. MECHANICAL SYSTEM

B. HYDRAULIC SYSTEM

Figure 20-3. Mechanical Advantage.

Section II. OIL PUMPS

20-4. Gear Type. Gear-type oil pumps are shown in figure 20-4. In this type, a primary gear, driven by an external member, drives a companion gear. Oil is forced into the pump cavity, around each gear, and out the other side into the oil passages. The pressure is derived from the action of the meshed gear teeth, which prevent oil from passing between the gears, and forces it around the outside of each gear instead. The oil pump incorporates a pressure relief valve, which is a spring-loaded ball that rises when the desired pressure is reached and allows the excess oil to be delivered to the inlet side of the pump.

20-5. Rotary Type. The rotor oil pump (fig. 20-5) makes use of an inner rotor with lobes that match similarly shaped depressions in the outer rotor. Figure 20-5 shows the manner in which the two rotors fit together. The inner rotor is off center from the outer rotor. The inner rotor is driven and, as it rotates, it carries the outer rotor around with it. The outer rotor floats freely in the pump body.

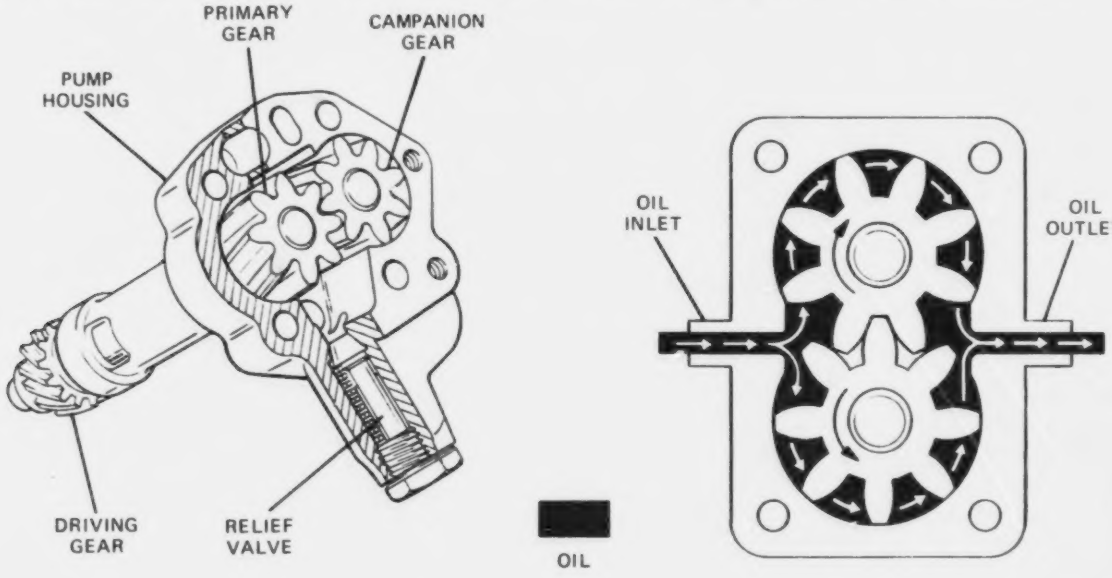


Figure 20-4. Gear-Type Pumps.

TA233669

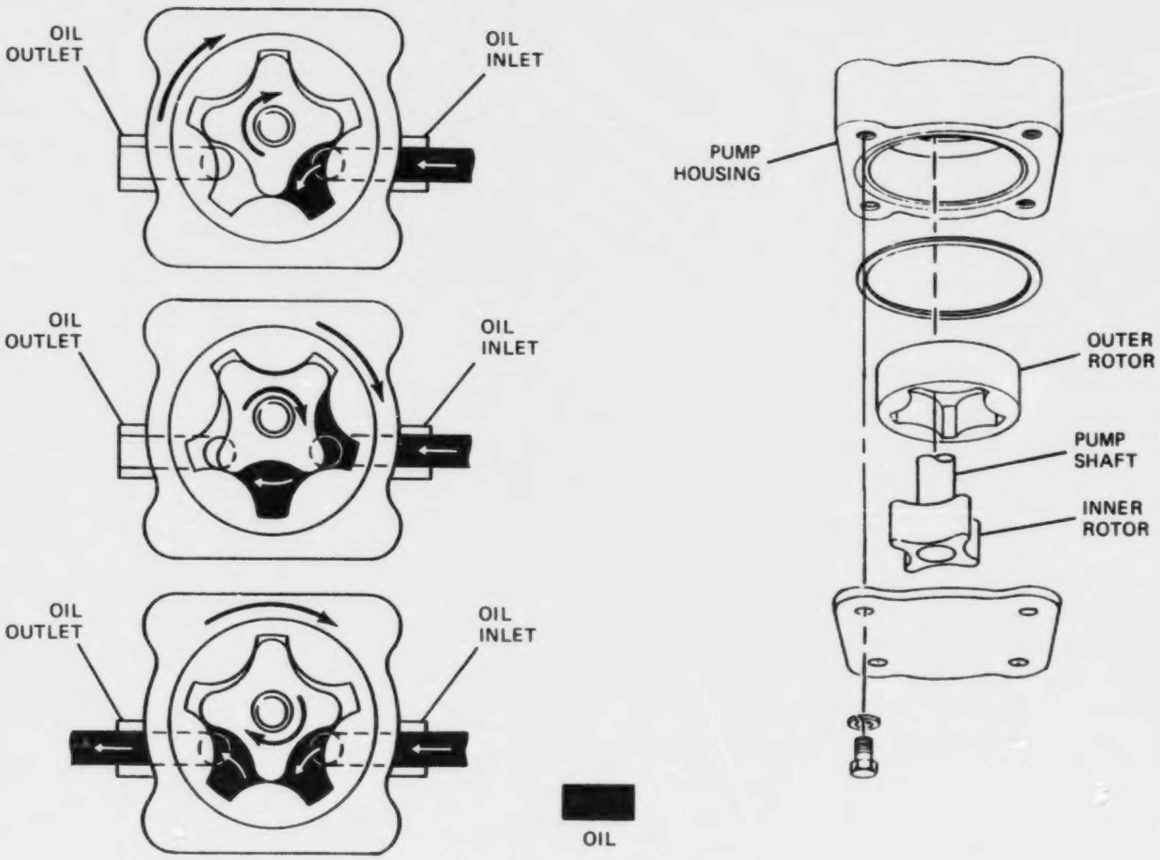


Figure 20-5. Rotary Pumps.

As the two rotors turn, the openings between them are filled with oil. This oil then is forced out from between the rotors as the inner-rotor lobes enter the openings in the outer lobes. This action is much like that in the gear-type pump.

20-6. Vane Type. The oil pump shown in figure 20-6 is a vane type. An integral steel rotor and shaft, one end supported in the pump flange and the other end in the cover, revolves in the body, the bore of which is eccentric to the rotor. Two sliding vanes are placed 180 degrees apart in slots in the rotor and are pressed against the body bore by springs in the slots. When the shaft is rotated, the vanes pick up oil at the inlet port and carry it around the body to the outlet side, where the oil is discharged. Pressure is produced by the wedging action of the oil as it is forced toward the outlet port by the vane.

20-7. Internal-External Gear Type. The internal-external gear pump is composed of a large internal gear, driven by an external gear offset from center. The space between the two gears is occupied by a filler block (fig. 20-7). As the small gear rotates, it meshes with, and drives, the larger gear. As the gears disengage and come in contact with the filler block, a differential in pressure is developed, causing oil to enter the pump. It then is transported past the filler block in the teeth of both gears. Because the gear teeth begin to mesh again and more oil is carried by the gears, pressure rises in the outlet chamber and exits through the outlet port.

TA233670

408

BEST COPY AVAILABLE

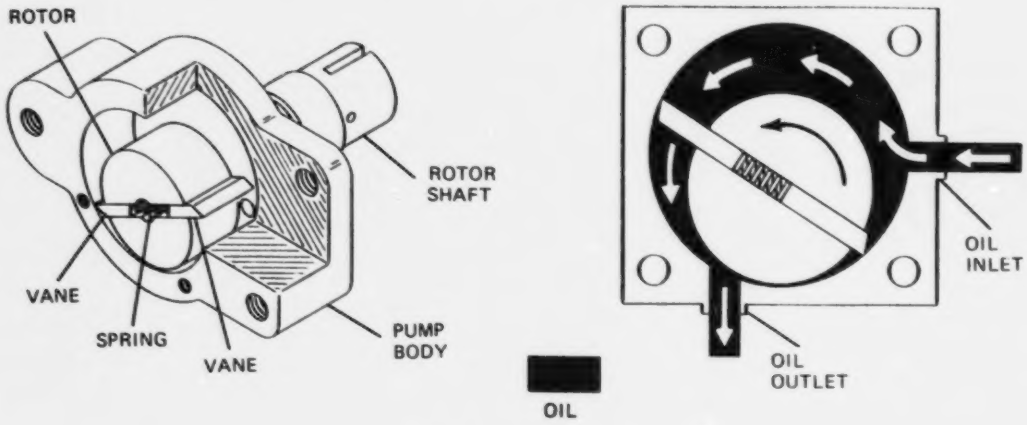

ROTOR
ROTOR SHAFT
VANE
SPRING
VANE
PUMP BODY
OIL
OIL INLET
OIL OUTLET

Figure 20-6. Vane Type.

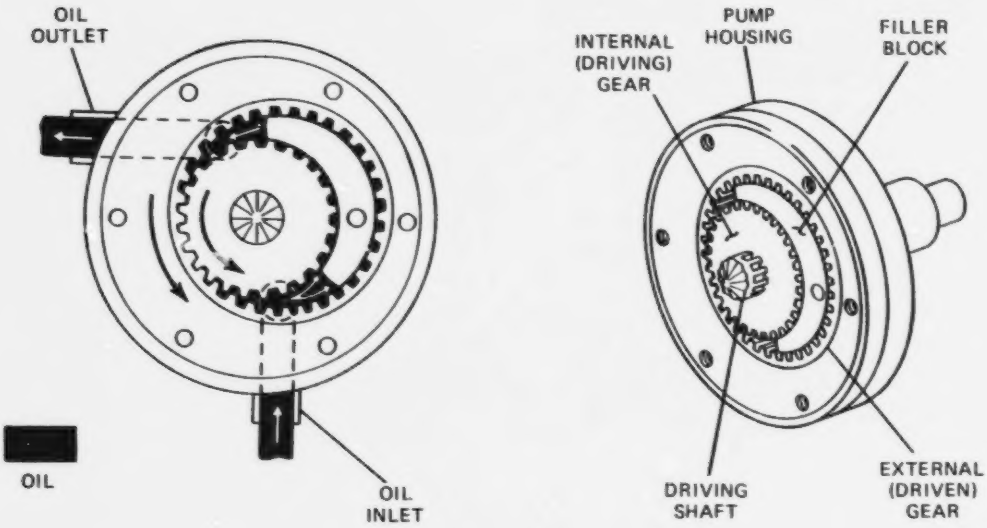

OIL OUTLET
OIL
OIL INLET
INTERNAL (DRIVING) GEAR
PUMP HOUSING
FILLER BLOCK
DRIVING SHAFT
EXTERNAL (DRIVEN) GEAR

Figure 20-7. Internal-External Gear Pump.

TA233671

Section III. SIMPLE HYDRAULIC JACK

20-8. Construction. A simple hydraulic jack is constructed using four basic components; each is discussed below.

a. Reservoir. The reservoir (fig. 20-8) is a storage location for the liquid medium. As the piston height is increased, fluid is transferred from the reservoir to the cylinder under piston B. The lowering of the piston displaces the fluid back to the reservoir.

b. Hand Pump. The hand pump (fig. 20-8) is a small-diameter piston and cylinder combination used to generate fluid pressure to raise the large piston.

c. Lifting Cylinder. The lifting cylinder (fig. 20-8) is composed of a large-bore piston and cylinder, which receives fluid pressure from the hand pump. The fluid pressure acts on the bottom of the large piston to raise it. The increased area of the piston allows heavy loads to be moved with relatively small pressure applied to the jack handle.

d. Check Valves. Two check valves (fig. 20-8) are placed in the system, one before the small piston, and one after. The check valves control the flow of the fluid to raise and lower the ram.

20-9. Operation (Fig. 20-8).

a. As the jack handle is pulled upward, piston A rises in cylinder A, pulling in oil from the reservoir through check valve 1.

b. As the jack handle is lowered, piston A forces oil from cylinder A through check valve 2 and into cylinder B.

c. As the oil is forced into cylinder B, it will push piston B upward, lifting the load through the ram.

d. Piston B will rise each time the jack handle is moved up and down.

20-10. Mechanical Advantage in the Jack. Because the hydraulic jack is capable of lifting heavy loads with relatively small amounts of physical force, the jack is known to have mechanical advantage. The mechanical advantage of the hydraulic jack is obtained from the following areas:

a. The mechanical advantage from the jack handle, which is in reality a lever (para 20-3). The hydraulic jack shown in figure 20-8 has a distance of 10 inches from the end of the jack handle to the piston and a distance of 1 inch from the piston to the fulcrum. The mechanical advantage of the lever is equal to:

$$10 \div 1 = 10.$$

b. The mechanical advantage in the hydraulic system, which is equal to the quotient of the areas of the lift piston divided by the pump piston, is equal to:

$$10 \div 1 = 10.$$

The total mechanical advantage of the jack then is calculated by multiplying the two mechanical advantages in a and b above as follows:

$$10 \times 10 = 100.$$

It is thus seen that the hydraulic jack shown in figure 20-8 produces a total mechanical advantage of 100.

410

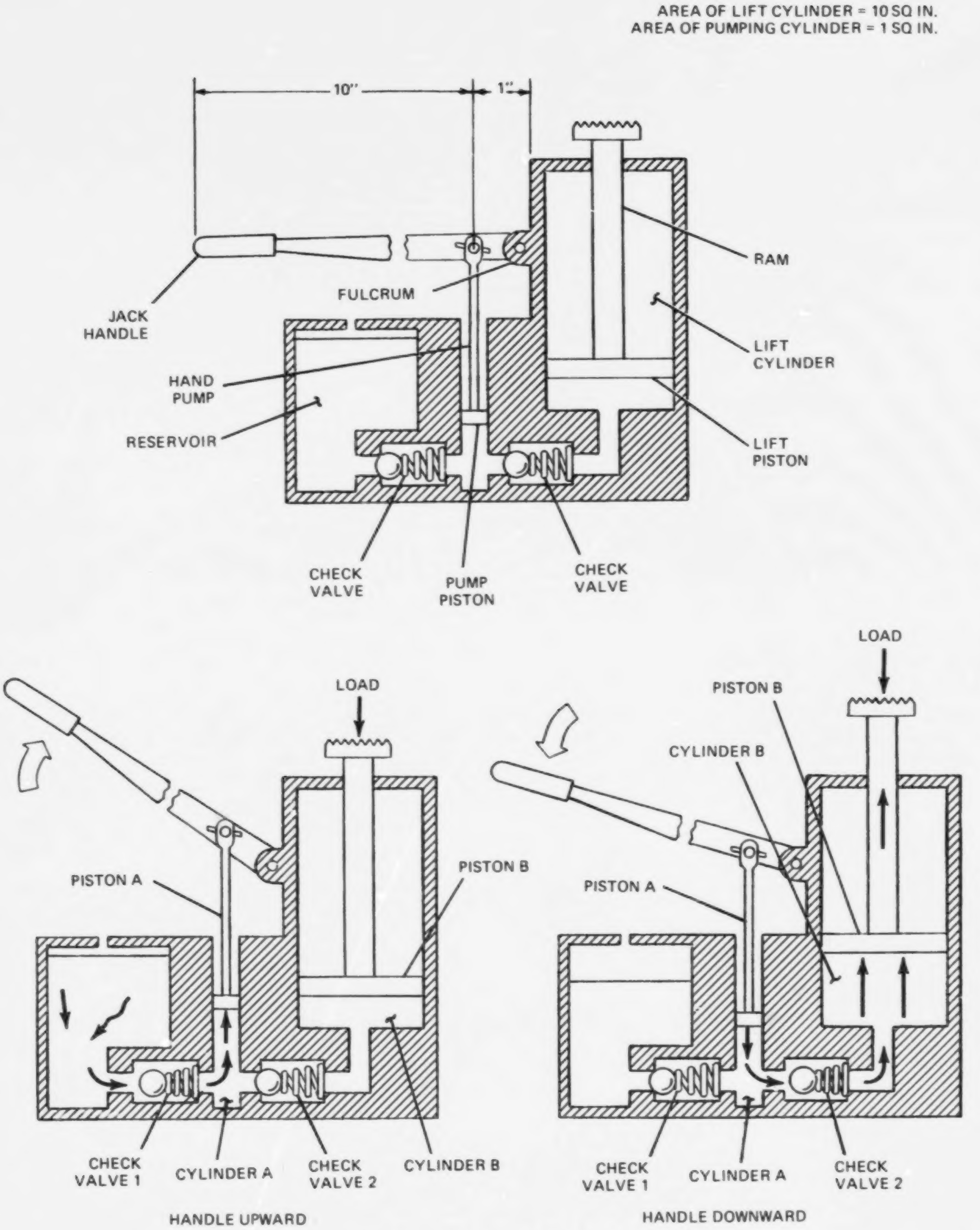

AREA OF LIFT CYLINDER = 10 SQ IN.
AREA OF PUMPING CYLINDER = 1 SQ IN.
10"
1"
RAM
FULCRUM
JACK HANDLE
LIFT CYLINDER
HAND PUMP
RESERVOIR
LIFT PISTON
CHECK VALVE
PUMP PISTON
CHECK VALVE
LOAD
PISTON A
PISTON B
CHECK VALVE 1
CYLINDER A
CHECK VALVE 2
CYLINDER B
HANDLE UPWARD
LOAD
PISTON B
CYLINDER B
PISTON A
CHECK VALVE 1
CYLINDER A
CHECK VALVE 2
HANDLE DOWNWARD

Figure 20-8. Simple Hydraulic Jack.

TA233672

CHAPTER 21

CLUTCHES, FLUID COUPLINGS, AND TORQUE CONVERTERS

Section I. CLUTCHES

21-1. Clutch Principles.

a. General. Automotive clutches depend on friction for their operation, whether it be solid friction as in the conventional clutch, or fluid friction and inertia as utilized in the fluid coupling and torque converter. The fluid coupling serves the same purpose as the conventional clutch, but the difference in the principle of operation makes it necessary to discuss the two mechanisms separately. Therefore, the first part of this chapter will be concerned with conventional clutches; fluid couplings and torque converters will be discussed in paragraphs 21-5 thru 21-9.

b. Purpose. A clutch in an automotive vehicle provides a means of connecting and disconnecting the engine from the power transmission system. Because the internal combustion engine does not develop a high starting torque, it must be disconnected from the power train and allowed to operate without load until it develops enough torque to overcome the inertia of the vehicle when starting from rest. The application of the engine power to the load must be gradual, to provide smooth engagement and to lessen the shock on the driving parts. After engagement, the clutch must transmit all the engine power to the transmission without slipping. Further, it is desirable to disconnect the engine from the power train during the time the gears in the transmission are being shifted from one gear ratio to another.

c. Operation. The transmission of power through the clutch is accomplished by bringing one or more rotating drive members secured to the crankshaft into gradual contact with one or more driven members secured to the unit being driven. These members are either stationary or rotating at different speeds. Contact is established and maintained by strong spring pressure controlled by the driver through the clutch pedal and suitable linkage. As spring pressure increases, the friction increases; therefore, when the pressure is light, the comparatively small amount of friction between the members permits a great deal of slippage. As the spring pressure increases, less slippage occurs until, when the full spring pressure is applied, the speed of the driving and driven members is the same. All slipping has stopped and there is, in effect, a direct connection between the driving and driven parts.

21-2. Clutch Elements. The principal parts of a clutch are the driving members, attached to the engine and turning with it; the driven members, attached to the transmission and turning with it; and the operating members, which include the spring or springs and the linkage required to apply and release the pressure that holds the driving and driven members in contact with each other. Figure 21-1 shows a clutch cutaway so operating members can be seen.

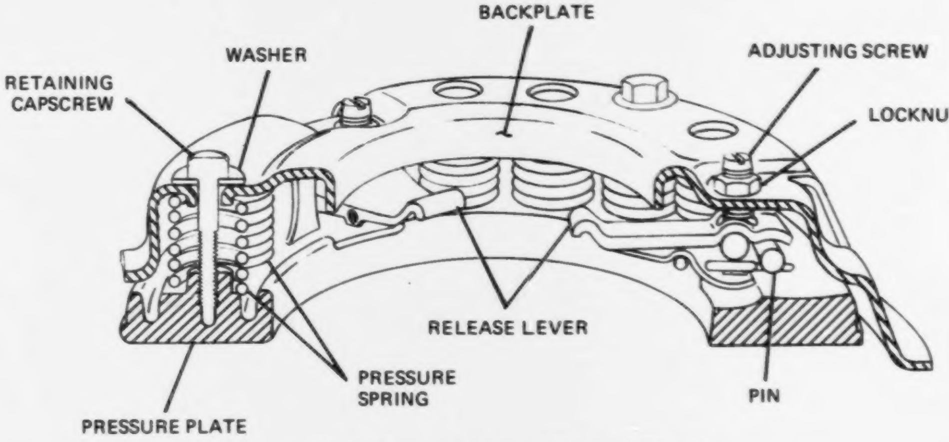


Figure 21-1. Components of Typical Clutch.

TA233673

a. *Driving Members*. The driving members of a clutch usually consist of two cast-iron plates or flat surfaces machined and ground to a smooth finish. Cast iron is recommended because it contains enough graphite to provide some lubrication when the driving member is slipping during engagement. One of these surfaces usually is the rear face of the engine flywheel, and the other is a heavy, flat ring with one side machined and surfaced. This part is known as the pressure plate. It is fitted into a steel cover, which also contains some of the operating members, and is bolted to the flywheel.

b. *Driven Members*.

(1) The driven member is a disk with a splined hub that is free to slide lengthwise along the splines of the clutch shaft. These same splines also transmit torque from the disk to the clutch shaft. (The driven member sometimes is referred to as the clutch plate, but the word disk will be used here to denote the driven member and thus differentiate between this part and the clutch pressure plate.) The clutch disk usually is made of spring steel in the shape of a single flat disk of a number of flat segments. Suitable frictional facings are attached to each side of the disk by means of copper rivets. These facings must be heat resistant because friction produces heat. The most commonly used facings are made of cotton and asbestos fibers woven or molded together and impregnated with resins or similar binding agents. Very often, copper wires are woven or pressed into the material to give it additional strength.

(2) In order to make clutch engagement as smooth as possible and eliminate chatter, several methods have been used to give a little flexibility to the driven disk. One type of disk is dished, so that the inner and outer edges of the friction facing make contact with the driving members first, and the rest of the facing makes contact gradually as the spring pressure increases and the disk is flattened out. In another type, the steel segments attached to the splined hub are twisted slightly, which also causes the facings to make gradual contact as the disk flattens out.

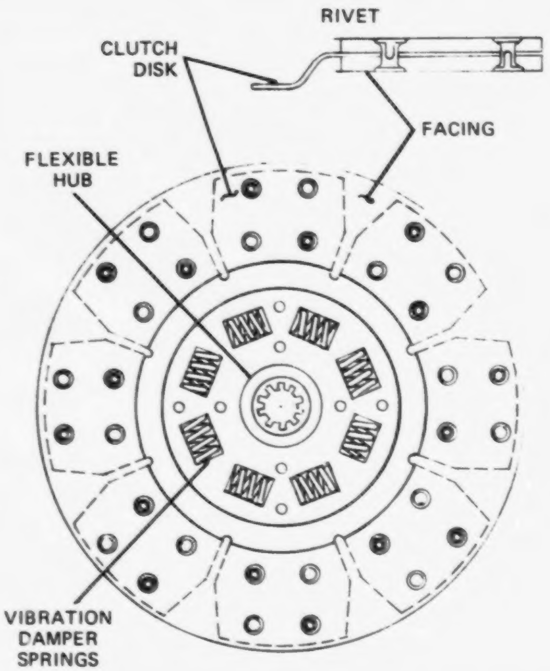


Figure 21-2. Clutch-Drive Plate with Flexible Center.

(3) The driven member of the clutch (fig. 21-2) usually is provided with a flexible center to absorb the torsional vibration of the crankshaft, which would be transmitted to the power train unless it were eliminated. The flexible center usually takes the form of steel compression springs placed between the hub and the steel disk. The springs permit the disk to rotate slightly with relation to its hub until, under extreme conditions, the springs are compressed fully and relative motion stops. Then the disk can rotate slightly backward as the springs decompress. This slight backward and forward rotation permitted by the springs allows the clutch shaft to rotate at a more uniform rate than the crankshaft, thereby eliminating some of the torsional vibration from the crankshaft and preventing the vibration from being carried back through the transmission.

c. *Operating Members*. The driving and driven members are held in contact by spring pressure. This pressure may be exerted by a single, large coil spring as shown in figures 21-3 and 21-4; a number of small helical springs located circumferentially around the outer portion of the pressure plate as shown in figure 21-1; or a one-piece conical or diaphragm spring as

TA233674

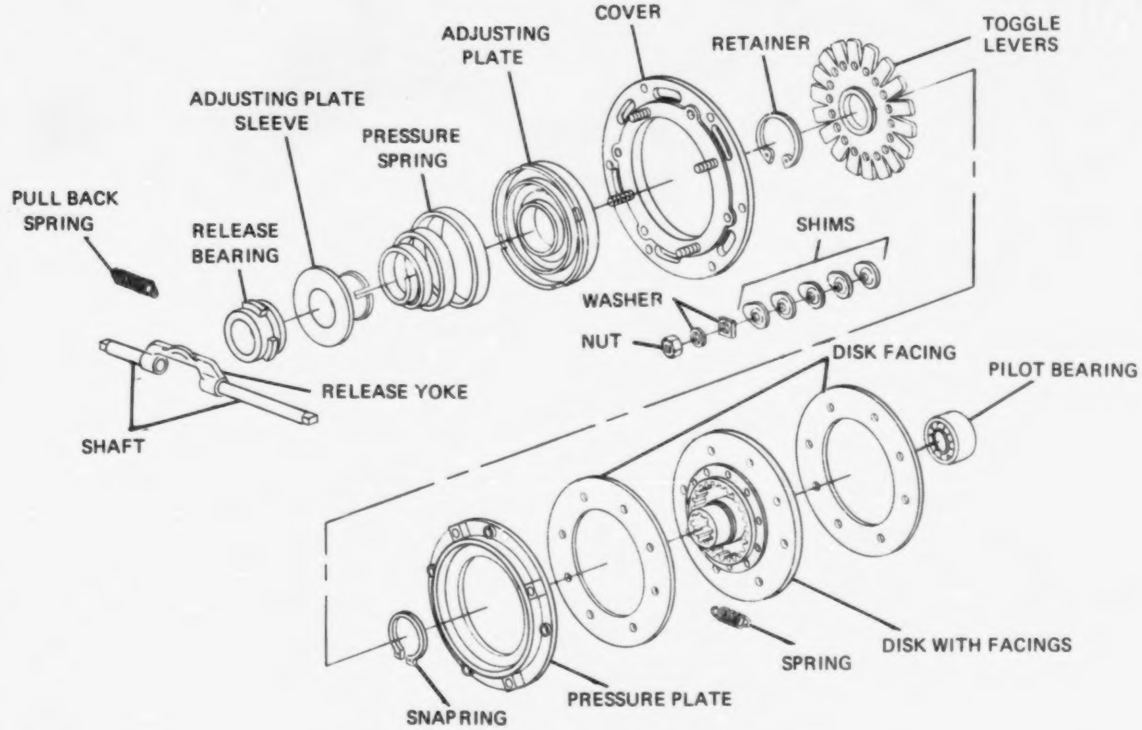

COVER
ADJUSTING PLATE
RETAINER
TOGGLE LEVERS
ADJUSTING PLATE SLEEVE
PRESSURE SPRING
PULL BACK SPRING
RELEASE BEARING
SHIMS
WASHER
NUT
DISK FACING
PILOT BEARING
RELEASE YOKE
SHAFT
SPRING
DISK WITH FACINGS
PRESSURE PLATE
SNAPRING

Figure 21-3. Single, Large Coil Spring Clutch.

shown in figures 21-5 and 21-6. In the helical-spring clutches, a system of levers pivoted on the cover forces the pressure plate away from the driven disk and against the pressure of the springs whenever the clutch release bearing moves forward against the inner ends of the levers. In single-spring clutches, the large coil spring holds the plates in contact. In diaphragm clutches, the dish-shaped diaphragm performs the same function. The clutch release (or throwout) bearing is a ball-thrust bearing contained in the clutch release bearing housing, or collar, mounted on a sleeve attached to the front of the transmission case. The release bearing (fig. 21-5 and 21-6) is connected through linkage to the clutch, and is moved by the release yoke to engage the release levers and move the pressure plate to the rear, thus separating the clutch driving members from the driven member when the clutch pedal is depressed by the driver.

21-3. Clutch Operating Systems.

a. General (Fig. 21-7). The automotive clutch, through spring pressure, normally is in an engaged position. The releasing of the clutch is accomplished through the use of a lever-type fork. The clutch, because it is a rotating member, requires that the fork release it through a release bearing that keeps the fork from rubbing directly on the clutch. The fork is activated by the operator through either a mechanical or hydraulic operating system.

b. Mechanical Operating System (Fig. 21-8). The mechanical clutch operating system is the most common. One type of system uses mechanical rod-type linkage while another type uses a flexible cable.

c. Hydraulic Operating System (Fig. 21-9). The hydraulic clutch operating system moves the fork by hydraulic pressure. Movement of the pedal creates pressure in the master cylinder, which actuates the slave cylinder. The slave cylinder then moves the clutch fork.

TA233675

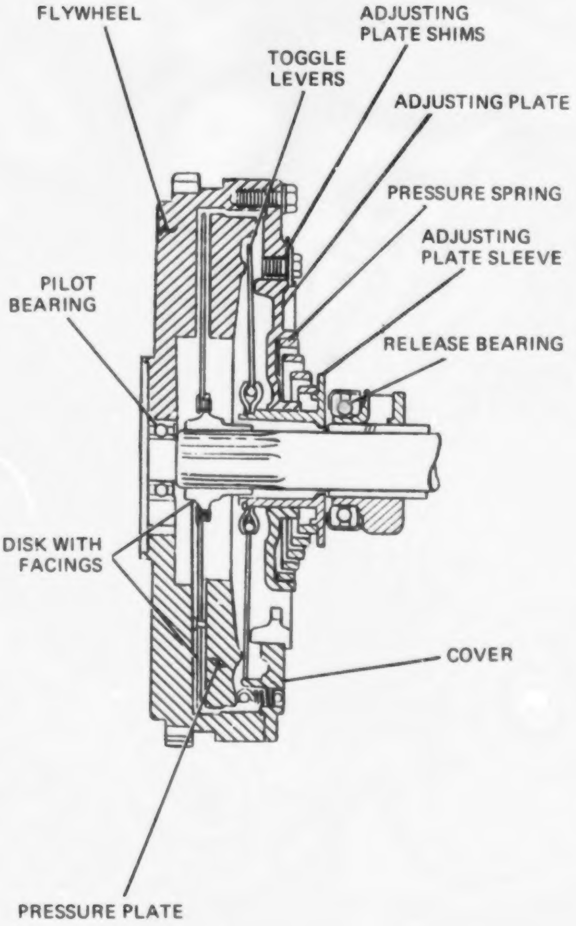

FLYWHEEL
ADJUSTING PLATE SHIMS
TOGGLE LEVERS
ADJUSTING PLATE
PRESSURE SPRING
ADJUSTING PLATE SLEEVE
PILOT BEARING
RELEASE BEARING
DISK WITH FACINGS
COVER
PRESSURE PLATE

Figure 21-4. Cross-Sectional View of Large Coil Spring Clutch.

21-4. Types of Clutches.

a. General. Automotive clutches may be classified according to the number of plates or disks used. The single-plate clutch contains one driven disk operating between the flywheel and the pressure plate (fig. 21-10). The flywheel is not considered to be a plate, even though it acts as one of the driving surfaces. A double-plate clutch is substantially the same except that another driven disk and an immediate driving plate (fig. 21-11) are added. A clutch having more than three driven disks (fig. 21-12) is referred to as a multiple-disk clutch. A further classification based on whether or not oil is supplied to the friction surfaces provides a positive method of identifying the many types of clutches in use: if oil is supplied, the clutch is known as the wet type; if oil is not supplied, the clutch is the dry type. Difference in the action of the clutches is largely a difference in the time of operation, the time required to engage the clutch depending on the number of plates, and the condition of the surfaces. A plate clutch will engage the load and start it in motion sooner than will a multiple-disk clutch. A dry clutch will be quicker to act than a wet clutch, in which the oil must be squeezed out from between the driven and driving members before engagement is accomplished. Plate clutches generally are used on light and medium weight vehicles, and the multiple-disk clutch is used on heavier vehicles in which the sudden action of the

TA233676

415

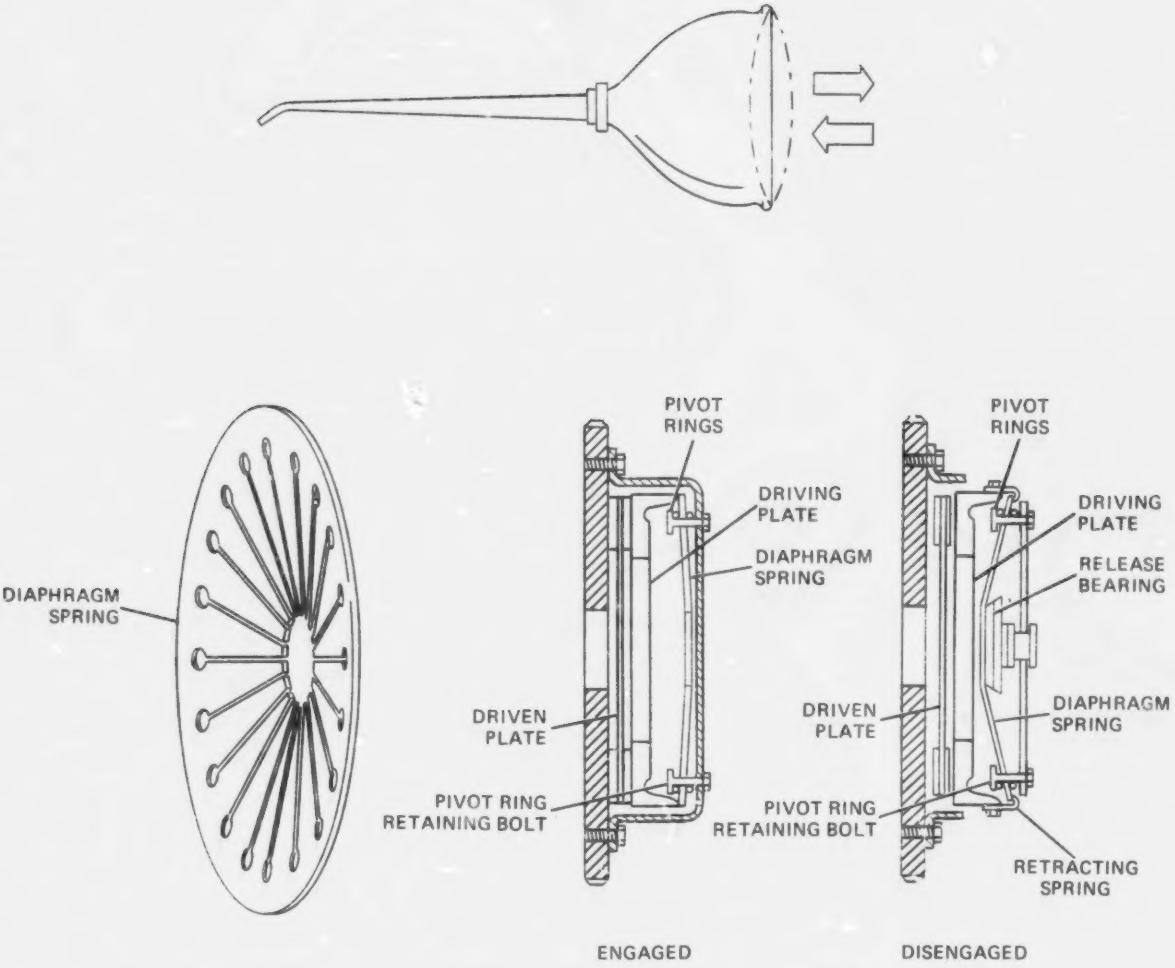
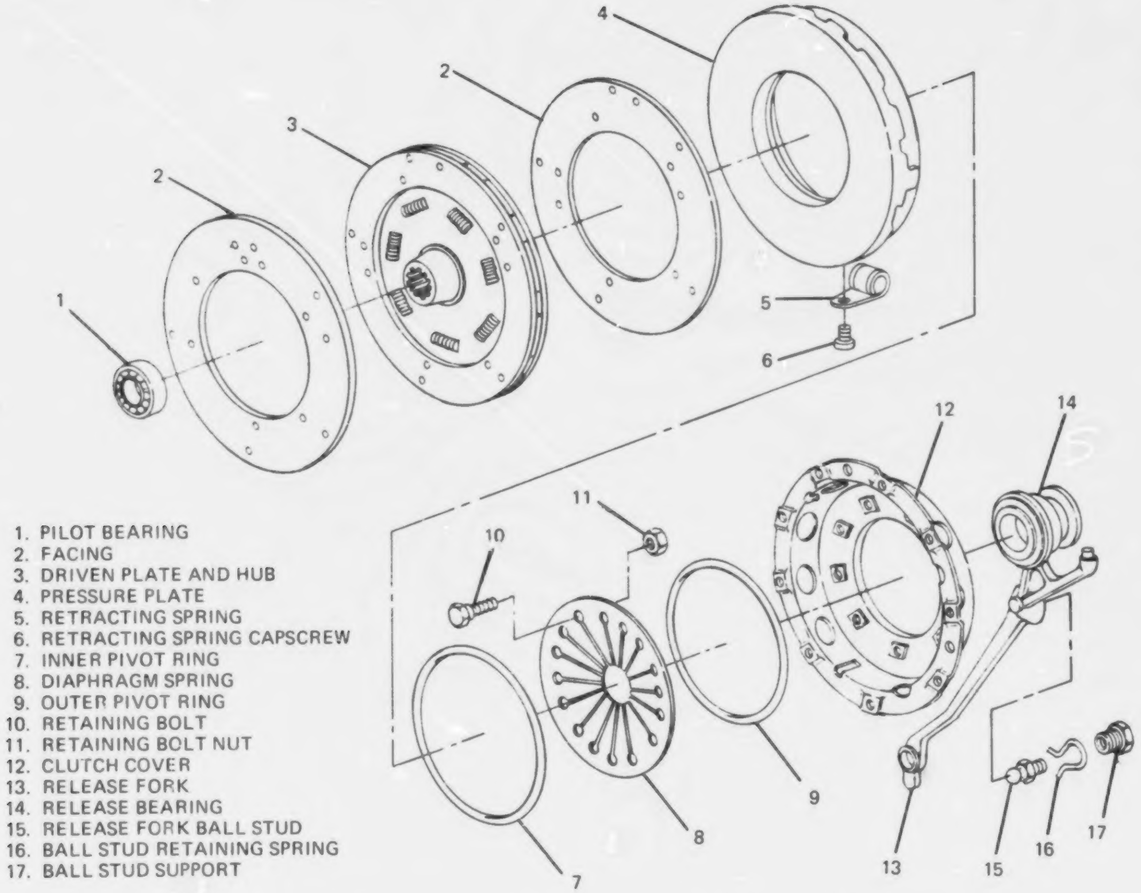

DIAPHRAGM
SPRING
PIVOT
RINGS
DRIVING
PLATE
DIAPHRAGM
SPRING
DRIVEN
PLATE
PIVOT RING
RETAINING BOLT
PIVOT
RINGS
DRIVING
PLATE
RELEASE
BEARING
DRIVEN
PLATE
DIAPHRAGM
SPRING
PIVOT RING
RETAINING BOLT
RETRACTING
SPRING
ENGAGED
DISENGAGED

Figure 21-5. Diaphragm Spring Clutch Operation.

TA233677


1
2
3
2
4
5
6
12
14
11
10
9
8
7
13
15
16
17

1. PILOT BEARING
2. FACING
3. DRIVEN PLATE AND HUB
4. PRESSURE PLATE
5. RETRACTING SPRING
6. RETRACTING SPRING CAPSCREW
7. INNER PIVOT RING
8. DIAPHRAGM SPRING
9. OUTER PIVOT RING
10. RETAINING BOLT
11. RETAINING BOLT NUT
12. CLUTCH COVER
13. RELEASE FORK
14. RELEASE BEARING
15. RELEASE FORK BALL STUD
16. BALL STUD RETAINING SPRING
17. BALL STUD SUPPORT

Figure 21-6. Diaphragm Spring Clutch – Disassembled View.

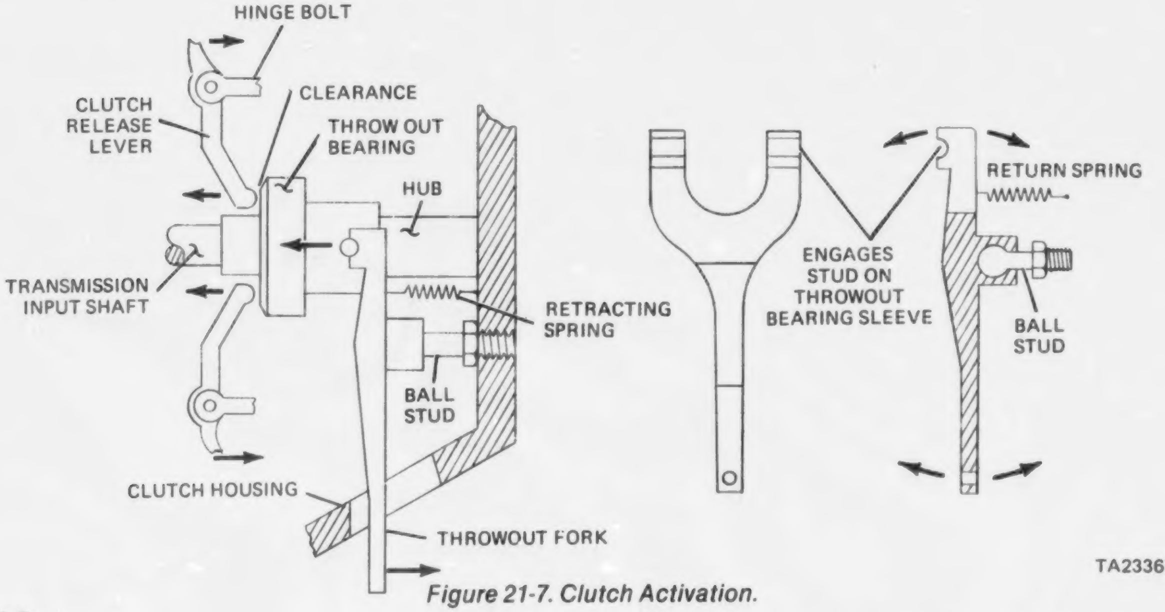
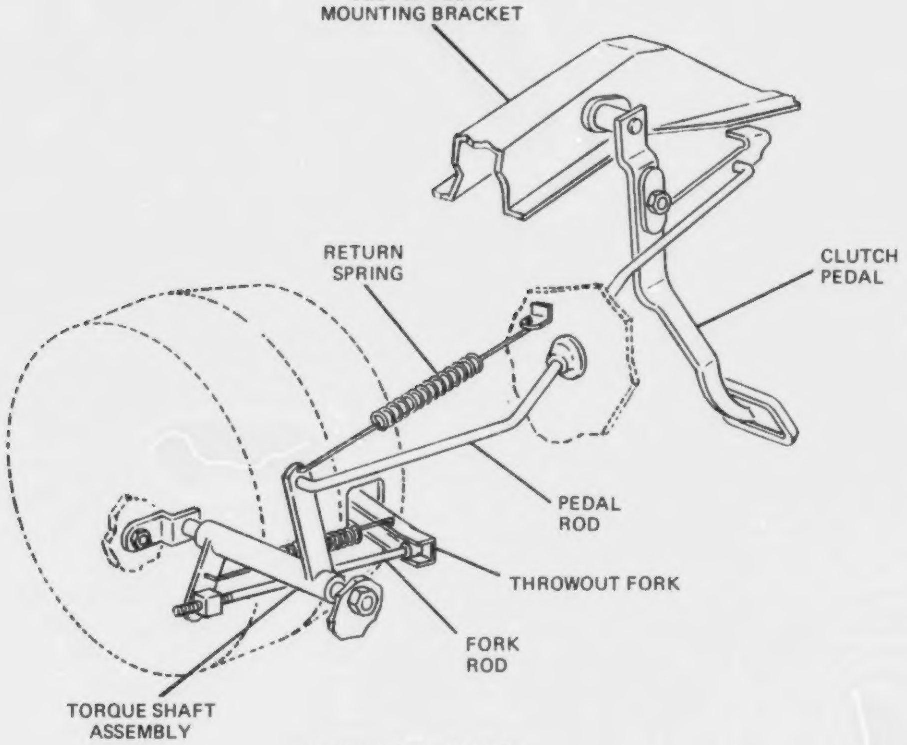
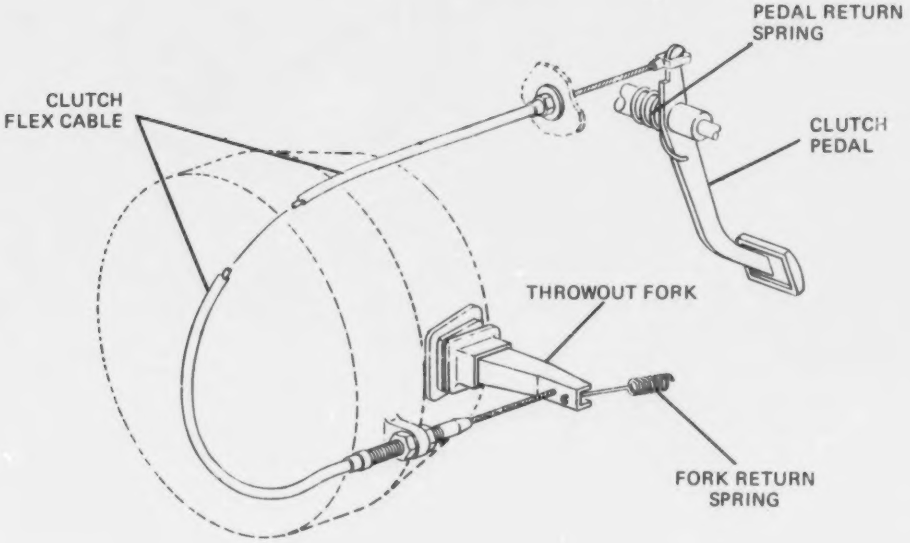

HINGE BOLT
CLUTCH RELEASE LEVER
CLEARANCE
THROW OUT BEARING
HUB
TRANSMISSION INPUT SHAFT
RETRACTING SPRING
BALL STUD
CLUTCH HOUSING
THROWOUT FORK
RETURN SPRING
ENGAGES STUD ON THROWOUT BEARING SLEEVE
BALL STUD
TA233678

Figure 21-7. Clutch Activation.

417


CLUTCH PEDAL
MOUNTING BRACKET
RETURN
SPRING
CLUTCH
PEDAL
PEDAL
ROD
THROWOUT FORK
FORK
ROD
TORQUE SHAFT
ASSEMBLY

MECHANICAL LINKAGE


PEDAL RETURN
SPRING
CLUTCH
FLEX CABLE
CLUTCH
PEDAL
THROWOUT FORK
FORK RETURN
SPRING

CABLE

Figure 21-8. Mechanical Operating Systems.

TA233679

1118

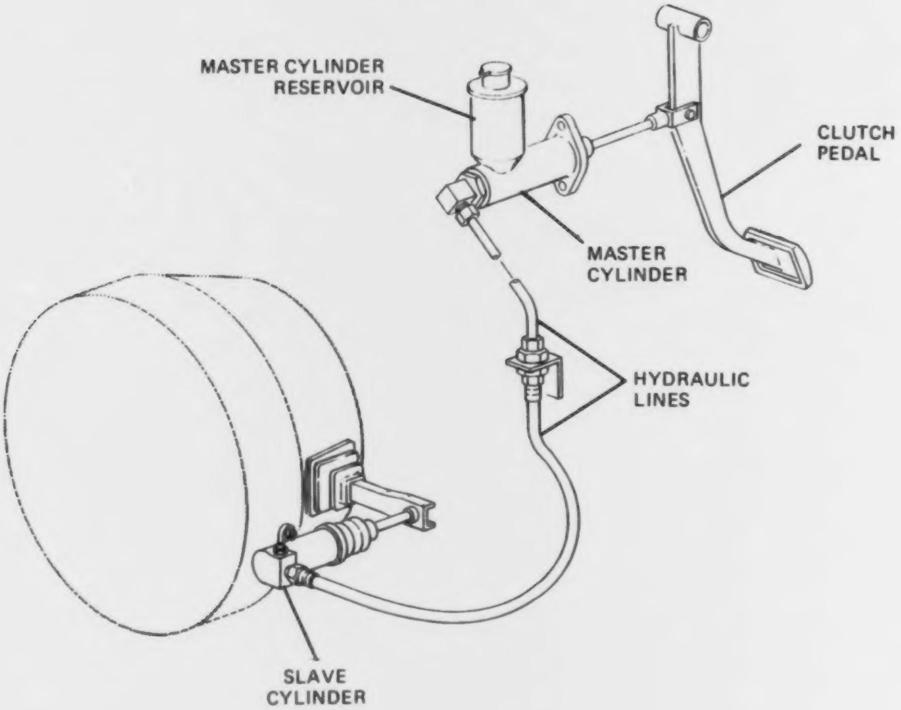


Figure 21-9. Hydraulic Operating Systems.

other type would impose a severe shock on the engine and power train when starting a heavy load.

b. Single Dry Plate (Fig. 21-10). The transmission is driven by a single friction plate that is sandwiched between the flywheel and an iron pressure plate. When the clutch is engaged fully, the driven disk is clamped firmly between the flywheel and the pressure plate by the pressure of the springs. When the operator disengages the clutch by depressing the pedal, the release yoke or fork is moved on its pivot, and pressure is applied to the release bearing sleeve, or collar, containing the release bearing. The rotating race of the release bearing presses against the clutch release levers and moves them on their pivot pins. The outer ends of the release levers, which are fastened to the cover, move the pressure plate to the rear, compressing the clutch springs and allowing the driving members to rotate independently of the driven member. The release yoke moves only on its pivot, which is fastened to the flywheel housing by means of a bracket or a transverse shaft. All parts of the clutch, except the release bearing and collar, rotate with the flywheel when the clutch is engaged. When the clutch is disengaged, the release bearing rotates with the flywheel, but the driven disk and the clutch shaft come to rest.

c. Diaphragm Clutch. In some clutches, a diaphragm is used instead of coil springs. It is a conical piece of spring steel punched as shown in figure 21-5 to give it greater flexibility. The diaphragm is positioned between the cover and the pressure plate so that the diaphragm spring is nearly flat when the clutch is in the engaged position. The action of this type of spring is similar to that of the bottom of an ordinary oilcan (fig. 21-5). The pressure of the outer rim of the spring on the pressure plate increases until it reaches the flat position and decreases as this position is passed. The outer rim of the diaphragm is secured to the pressure plate and is pivoted on rings approximately 1 inch from the outer edge so that the application of pressure at the inner section will cause the outer rim to move away from the flywheel and draw the pressure plate away from the clutch disk, releasing or disengaging the clutch. When the pressure is released from the inner section, the oilcan action of the diaphragm

TA233680

419

BEST COPY AVAILABLE

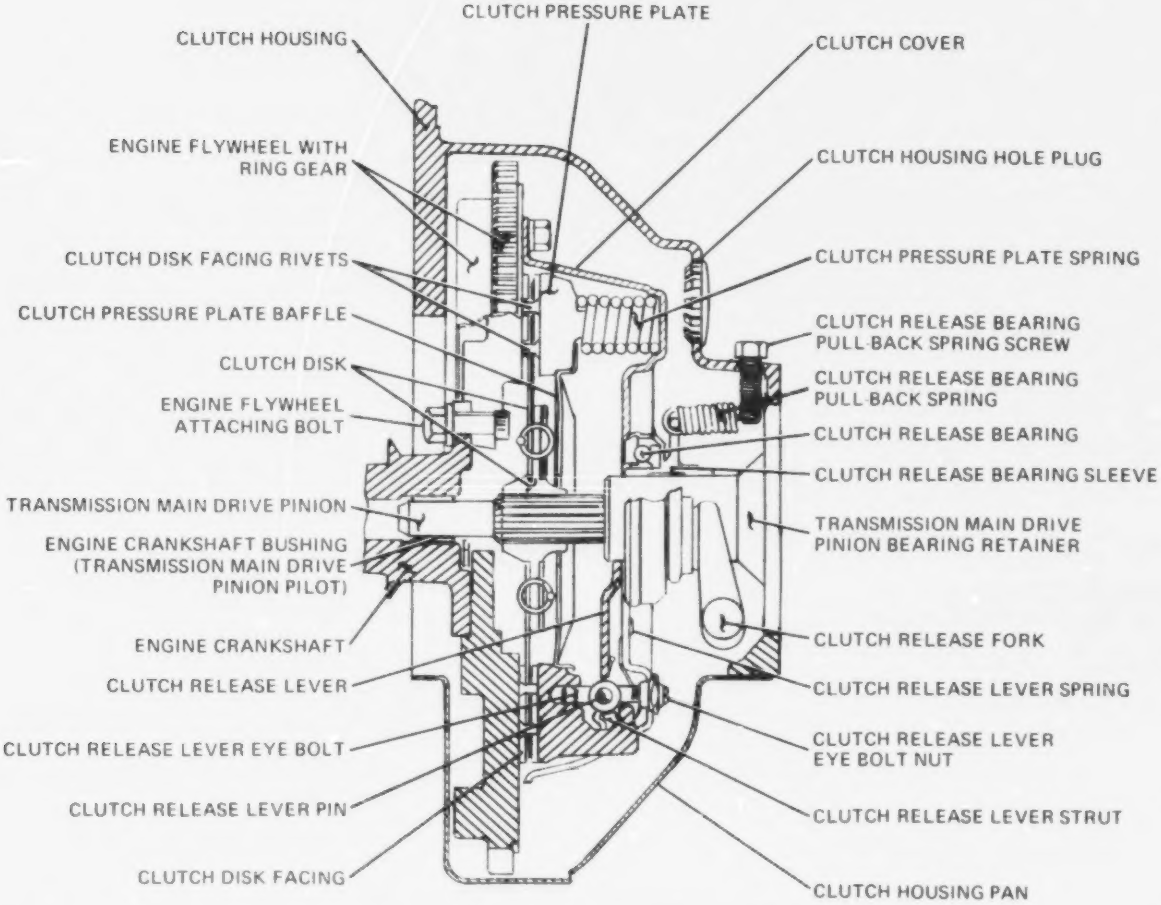

CLUTCH PRESSURE PLATE
CLUTCH HOUSING
CLUTCH COVER
ENGINE FLYWHEEL WITH RING GEAR
CLUTCH HOUSING HOLE PLUG
CLUTCH DISK FACING RIVETS
CLUTCH PRESSURE PLATE SPRING
CLUTCH PRESSURE PLATE BAFFLE
CLUTCH RELEASE BEARING PULL-BACK SPRING SCREW
CLUTCH DISK
CLUTCH RELEASE BEARING PULL-BACK SPRING
ENGINE FLYWHEEL ATTACHING BOLT
CLUTCH RELEASE BEARING
CLUTCH RELEASE BEARING SLEEVE
TRANSMISSION MAIN DRIVE PINION
TRANSMISSION MAIN DRIVE PINION BEARING RETAINER
ENGINE CRANKSHAFT BUSHING (TRANSMISSION MAIN DRIVE PINION PILOT)
ENGINE CRANKSHAFT
CLUTCH RELEASE FORK
CLUTCH RELEASE LEVER
CLUTCH RELEASE LEVER SPRING
CLUTCH RELEASE LEVER EYE BOLT
CLUTCH RELEASE LEVER EYE BOLT NUT
CLUTCH RELEASE LEVER PIN
CLUTCH RELEASE LEVER STRUT
CLUTCH DISK FACING
CLUTCH HOUSING PAN

Figure 21-10. Single Dry Plate Clutch.

causes the inner section to move out, and the movement of the outer rim forces the pressure plate against the clutch disk, thus engaging the clutch.

d. Multiple-Disk Clutch. Typical multiple-disk clutches are shown in figures 21-11 and 21-12. Disks ranging in numbers from 2 to 10 (and often as many as 11 driving and 10 driven disks for heavy vehicles) are used. The driving disks have lugs similar to gear teeth around their outside edges. These mesh with internal splines in the clutch case, which is bolted to and rotates with the flyweel. The driven disks are carried on parallel pins, which are solidly set in the clutch spider. This construction permits movement of all the disks and the pressure plate in order to provide clearance between them. When the clutch is engaged, the spring moves the pressure plate forward, holding all the disks together firmly. This causes the clutch spider to revolve and turn the clutch shaft to which it is keyed. In multiple-disk clutches, the facings usually are attached to the driving disks. This reduces the weight of the driven disks and, consequently, their tendency to continue spinning after the clutch is released. Because of the considerable number of disks involved, the pressure plate has to move farther to separate the disks completely than it does in clutches having fewer driving and driven members. There is, therefore, less mechanical advantage on the clutch pedal and a greater foot pressure is required to depress it.

e. In a wet-type clutch, the disks and the entire internal assembly run in an oil bath. The operation of this type of clutch is similar to that of the dry type, except that the friction surfaces are

TA233681

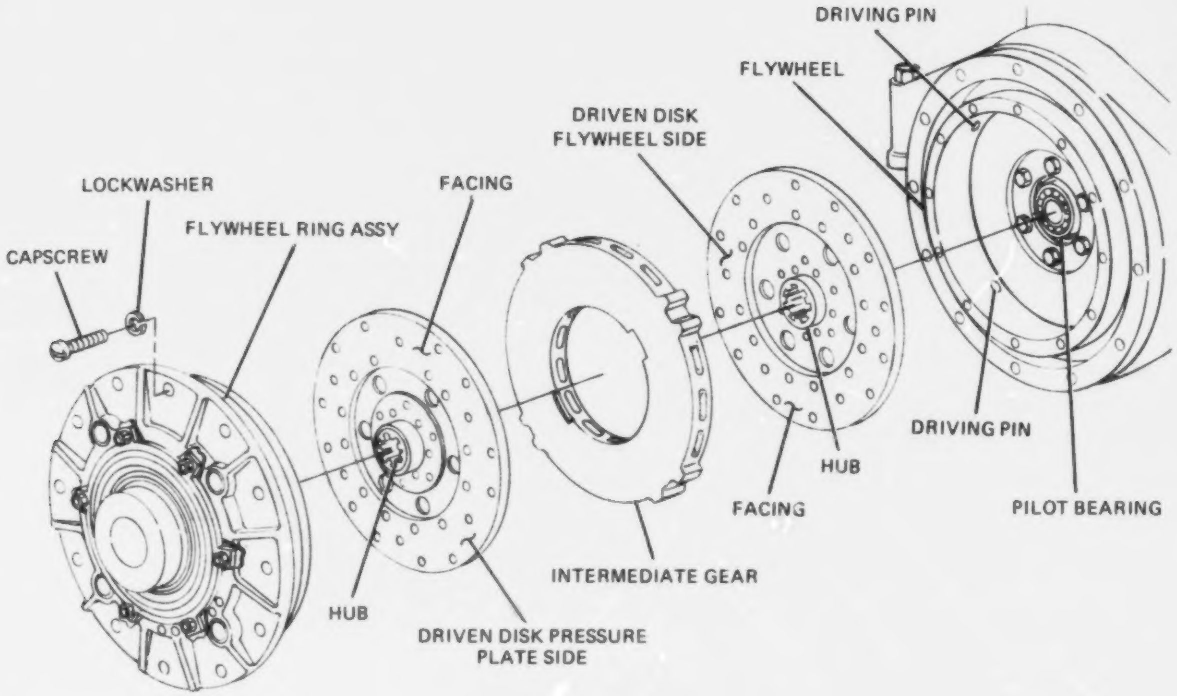

DRIVING PIN
FLYWHEEL
DRIVEN DISK FLYWHEEL SIDE
LOCKWASHER
FACING
FLYWHEEL RING ASSY
CAPSCREW
DRIVING PIN
HUB
FACING
PILOT BEARING
INTERMEDIATE GEAR
HUB
DRIVEN DISK PRESSURE PLATE SIDE

Figure 21-11. Clutch Disk with Two Driven Disks.

made of different materials and the gradual engagement between the driving and driven members is caused by pressing the oil from between the disks. As the oil is eliminated, the friction increases.

f. Helical Spring (Semicentrifugal). Many passenger car clutches are of the semicentrifugal type shown in figure 21-13, in which the pressure between the plates is increased as the speed of the clutch increases. This is accomplished by means of centrifugal weights built into the outer ends of the release levers so that the outward pull of centrifugal force is transformed into pressure on the plate. This construction permits the use of relatively light clutch springs, thus facilitating the depression of the clutch pedal for gear shifting.

TA233682

421

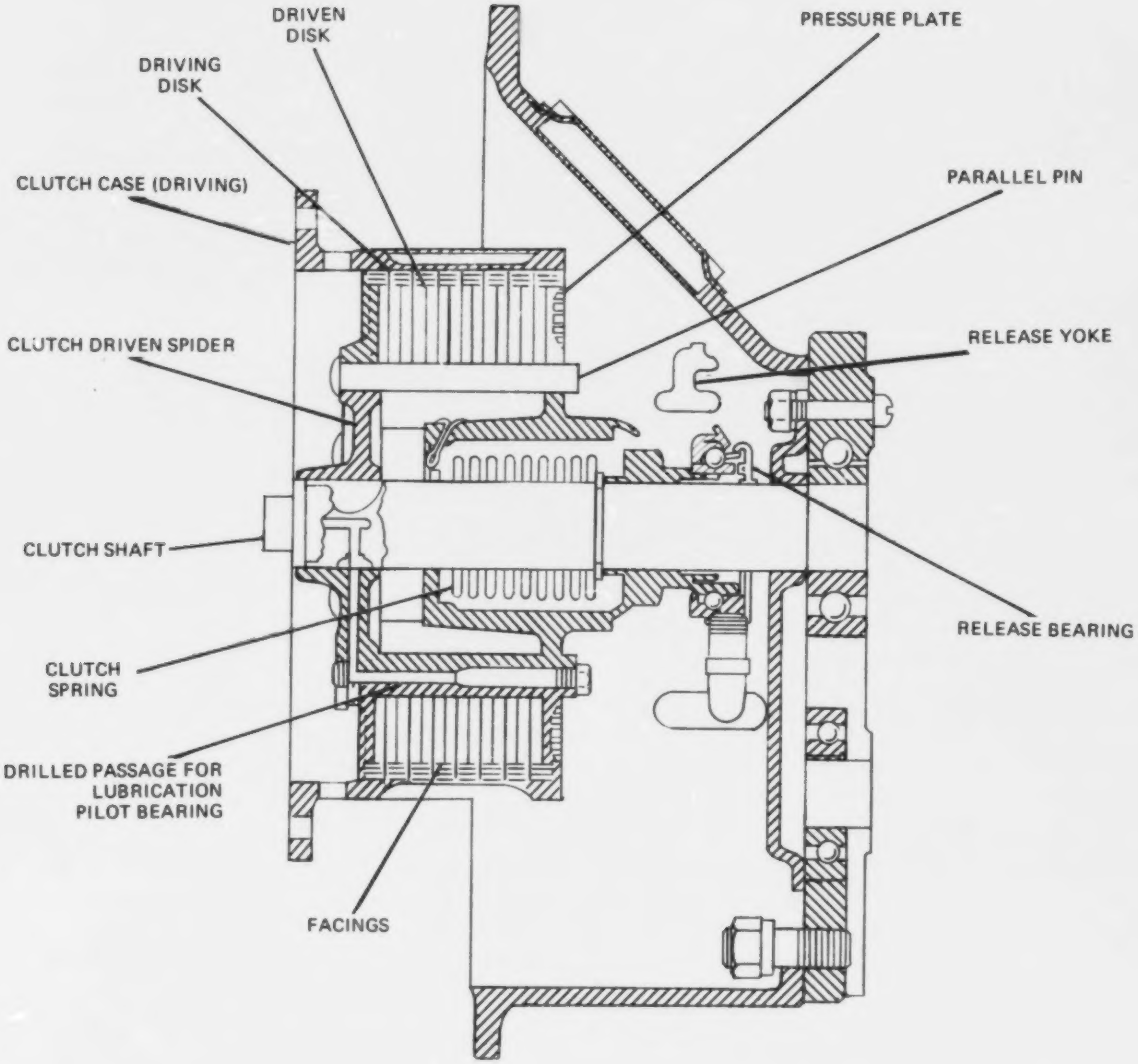

DRIVEN DISK
DRIVING DISK
PRESSURE PLATE
CLUTCH CASE (DRIVING)
PARALLEL PIN
CLUTCH DRIVEN SPIDER
RELEASE YOKE
CLUTCH SHAFT
RELEASE BEARING
CLUTCH SPRING
DRILLED PASSAGE FOR LUBRICATION PILOT BEARING
FACINGS

Figure 21-12. Multiple-Disk Clutch.

TA233683

422

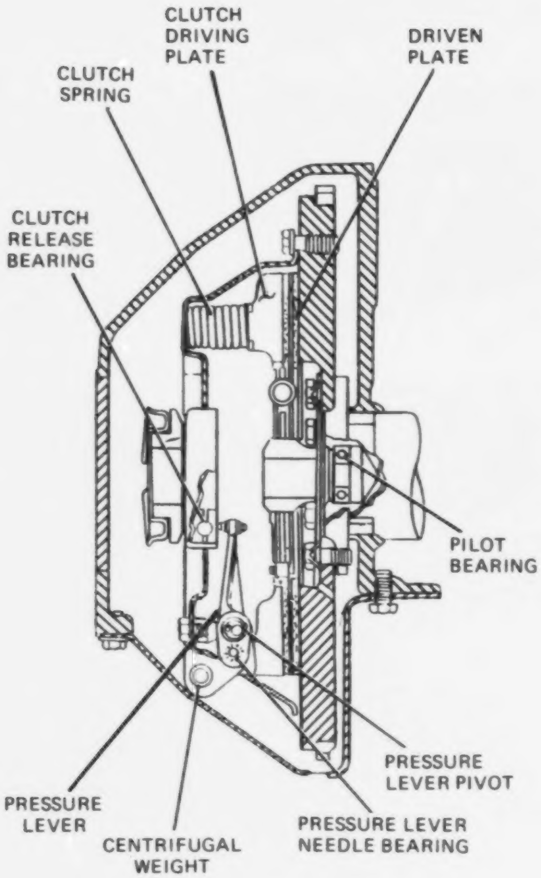

CLUTCH DRIVING PLATE
DRIVEN PLATE
CLUTCH SPRING
CLUTCH RELEASE BEARING
PILOT BEARING
PRESSURE LEVER PIVOT
PRESSURE LEVER
CENTRIFUGAL WEIGHT
PRESSURE LEVER NEEDLE BEARING

Figure 21-13. Semicentrifugal Clutch - Cross-Sectional View.

Section II. FLUID COUPLINGS

21-5. Principles. The fluid coupling (fig. 21-14) is used either with a conventional clutch and transmission or as a part of an automatic transmission, in which case, it may replace the clutch. The principle of this type of drive is illustrated by the action of two electric fans facing each other, one with the power connected and the other with the power disconnected. As the speed of the power-driven fan is increased, the flow of air transmits power to the motionless fan and it begins to rotate. The free-running fan gains speed until it is rotating almost as rapidly as the power-driven fan. The same action takes place in the fluid coupling except that oil, instead of air, transmits the power.

21-6. Operation.

a. Coupled Phase. The fluid coupling consists of an impeller, or driving torus, driven by the engine and a turbine, or driven torus, mounted on the driven shaft. These parts are shown in figure 21-14 and depicted schematically in figure 21-15. There is no metallic connection between the two torus members. The assembly is kept filled with oil under control of a relief valve, by means of high-capacity pumps. When the crankshaft and impeller rotate, the oil is thrown by centrifugal force from the center to the outside edge of the impeller between the vanes. This increases the velocity of the oil and increases its

TA233684

423

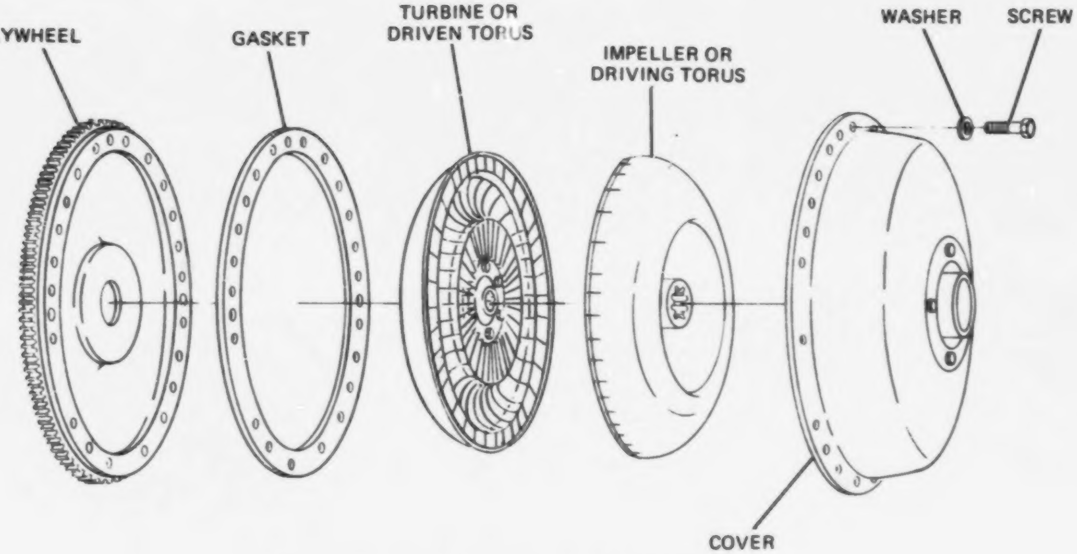


Figure 21-14. Fluid Coupling – Disassembled View.

energy. The oil then enters the turbine vanes at the outside and flows toward the center, giving a rotating motion to the turbine. Both members of the drive are of similar construction, so that when the vehicle is coasting in gear, the wheels drive the engine. In this case, the oil circulates in a reverse direction. The engine can thus brake the vehicle, as with a vehicle equipped with a conventional clutch.

b. Uncoupled Phase. When the engine is idling, the energy supplied to the oil is not enough to rotate the turbine. As the amount of slip is determined by the torque required by the driven member, the slip is 100 percent with the vehicle stationary, but drops quickly as the vehicle gathers speed. In some arrangements, it is less than 1 percent during normal operation above 30 mph. The main advantage of the fluid coupling is that it eliminates torsional vibration and provides a smooth, jerkless acceleration because of the cushioning of the fluid medium between the two members.

TA233685

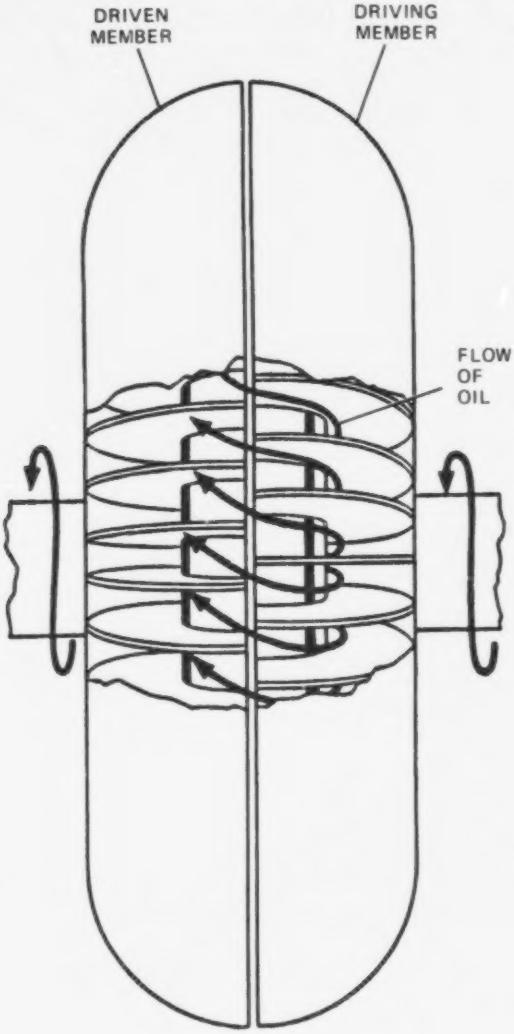


Figure 21-15. Fluid Coupling – Schematic View.

Section III. TORQUE CONVERTERS

21-7. Principles. In some respects, the torque converter is like the fluid coupling. It has driving and driven members with vanes. Oil is passed from the driving to the driven member when the coupling is in operation, thereby transmitting driving force to the driven member. However, in the torque converter, the vanes are curved and additional rotatable members provide the means of increasing torque through the unit. These additional members can reverse the direction of the moving oil before it reenters the driving member; this nullifies any negative effect produced by vane curvature, as explained in paragraph 21-8. Thus, the torque converter not only acts as a fluid coupling, it also provides a speed-producing, torque-multiplying connection be-

TA233686

425

tween the driving and the driven shafts. It actually can take the place of the conventional transmission because, with it, there is no need for gearshifting; the vehicle can be accelerated from a standing stop to high speed with the torque converter providing, in effect, the varying gear ratios. In actual practice, the torque converter is used with a gear system (including planetary gears) to provide a high range (for normal operation), a low range (for steep hills, or pulling out of mud), reverse, and neutral. There also may be a parking position at which the gear system is locked.

21-8. Operation.

a. All torque converters have a driven member (called the turbine) and a driving member (called the pump). In addition, they have one or more other rotatable members (or elements) placed between the pump and the turbine that have the purpose of changing the direction of oil flow under high-torque-multiplication operation. Figures 21-16 and 21-17 show torque converters in sectional and cutaway views.

b. The primary action of the torque converter results from the action of the pump in passing oil at an angle into the blades of the turbine (fig. 21-16). The oil pushes against the faces of the turbine vanes, thereby tending to cause the turbine to rotate in the same direction as the pump. If the pump is rotating much more rapidly than the turbine, the oil enters the turbine and pushes against the turbine vanes with great force. As the oil passes around through the turbine (fig. 21-17), it imparts force against the turbine vanes, all along the vanes. But it does not give up all of its force of motion to the turbine vanes. It still has considerable energy, even though passing through the turbine has reversed its direction of motion as shown in figure 21-17. If this reversed direction of motion were not changed, the oil would reenter the pump in a direction opposing pump rotation. It would act as a brake on the pump, tending to slow it down. Considerable engine power would be consumed in overcoming this action. However, the additional members in the torque converter again change the direction of the oil before it reenters the pump, thereby avoiding loss of power. As can be seen in figure 21-18, the curved blades of the added members (secondary stator and primary stator) reverse the direction of the oil into a forward, or helping, direction before it reenters the pump. Then, the oil once more is passed into the tubine from the pump, adding more push to the turbine vanes. During this action, the stators are stationary and act simply as oil-direction reversers.

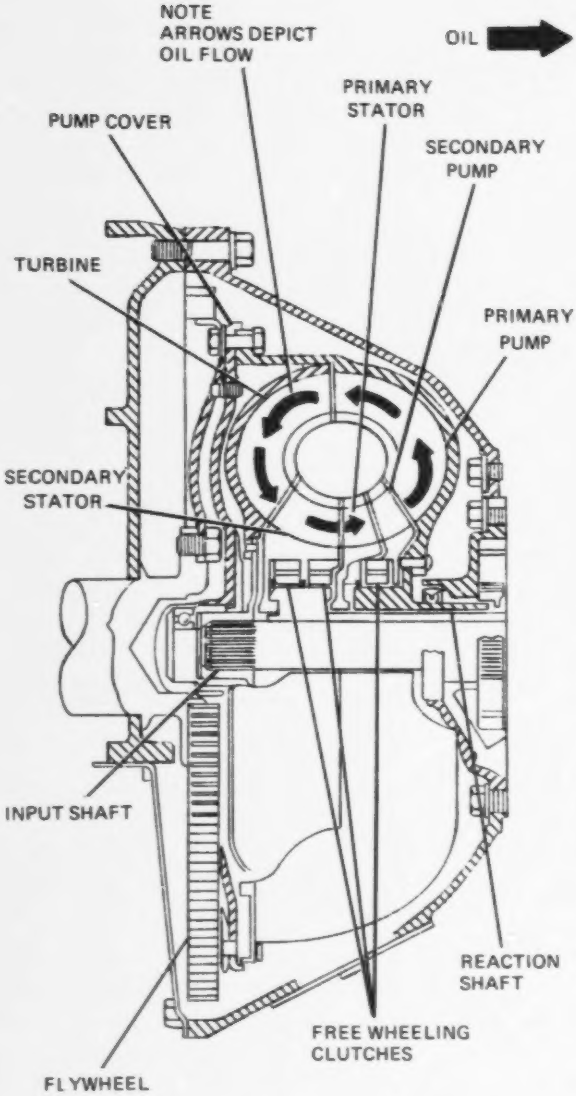


Figure 21-16. Torque Converter – Partial Cutaway View.

c. It is this continuous passing of the oil from the pump into the turbine, back to the pump,

TA233687

426

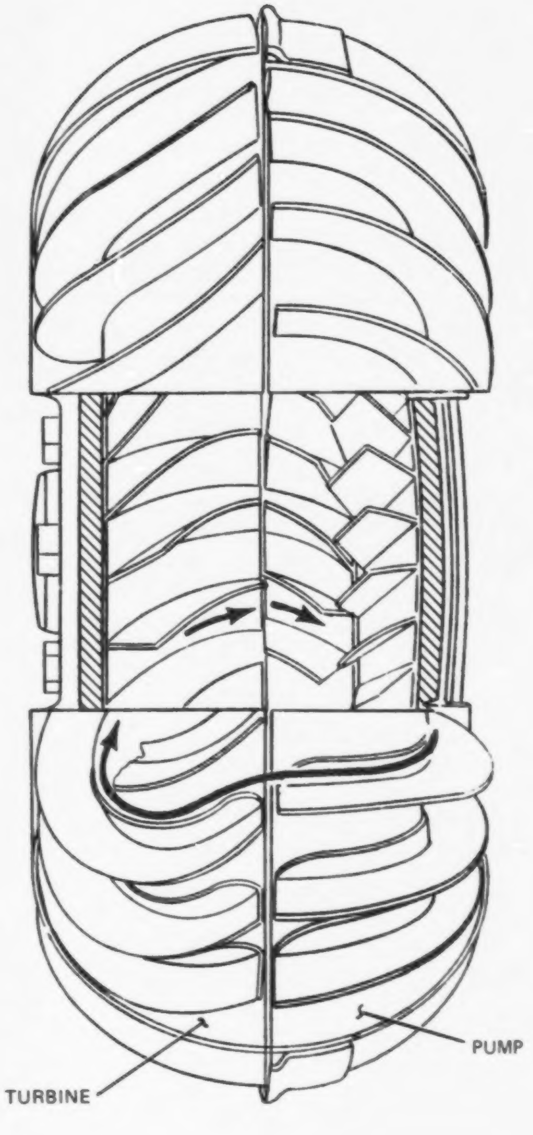


Figure 21-17. Torque Converter Cutaway so Curvature of Vanes and Oil Flow is Visible.

where it picks up more energy of motion, and then back into the turbine again, that produces the torque multiplication. Each time the oil passes from the pump to the turbine, it gives a push to the turbine. The oil still has energy of motion after it leaves the turbine and is reversed in direction by the stators and secondary pump. When it comes around to the turbine again, it gives more of this push to the turbine. Repeated applications of this push increases the total push so that, when the turbine is rotating at very slow speed with the pump rotating at high speed, the torque at the output shaft (attached to turbine) may be several times the torque at the input shaft (attached to the engine).

d. In actual operation, the secondary stator and primary stator are stationary when there is a great difference between pump and turbine speed. At the same time, the secondary pump is overrunning, or running faster than, the primary pump; the secondary pump does not enter into the converter action at all at this time. The secondary pump is mounted on a freewheeling or overrunning clutch very similar to the overrunning clutch used in automotive starters (para 23-7). The freewheeling clutch permits the secondary pump to run freely in one direction, but, when it attempts to slow down below shaft speed, it locks on the shaft because the rollers jam between the race and notches in the hub as shown in figure 21-18. However, when the turbine is stopped or turning slowly and the pump is turning rapidly, the direction of oil flow is as shown by the arrows in figure 21-17. As it moves to the secondary pump, it strikes the back sides of the secondary pump vanes, pushing the secondary pump ahead so that it overruns. Under this condition, the secondary pump vanes simply are moving out of the way of the oil. The secondary pump enters the action only when the pump and turbine are turning at about the same speeds, as described below.

e. When the turbine speed increases due to the application of the torque, so that it turns at more nearly the same speed as the pump, the oil leaves the turbine vanes with less of the reverse direction of motion mentioned above. Consequently, it begins to strike the back sides of the secondary stator vanes so the secondary stator now begins to overrun on its overrunning clutch. It is no longer needed, and therefore, in effect, it moves out of the way by overrunning or freewheeling.

f. When turbine speed increases to nearly pump speed, as when cruising at steady speed along the highway, the oil leaves the turbine vanes with very little reverse direction of motion. The primary stator also begins to overrun because the oil begins to strike the back sides of its vanes. At the same time, the oil begins to strike the front

TA233688

427

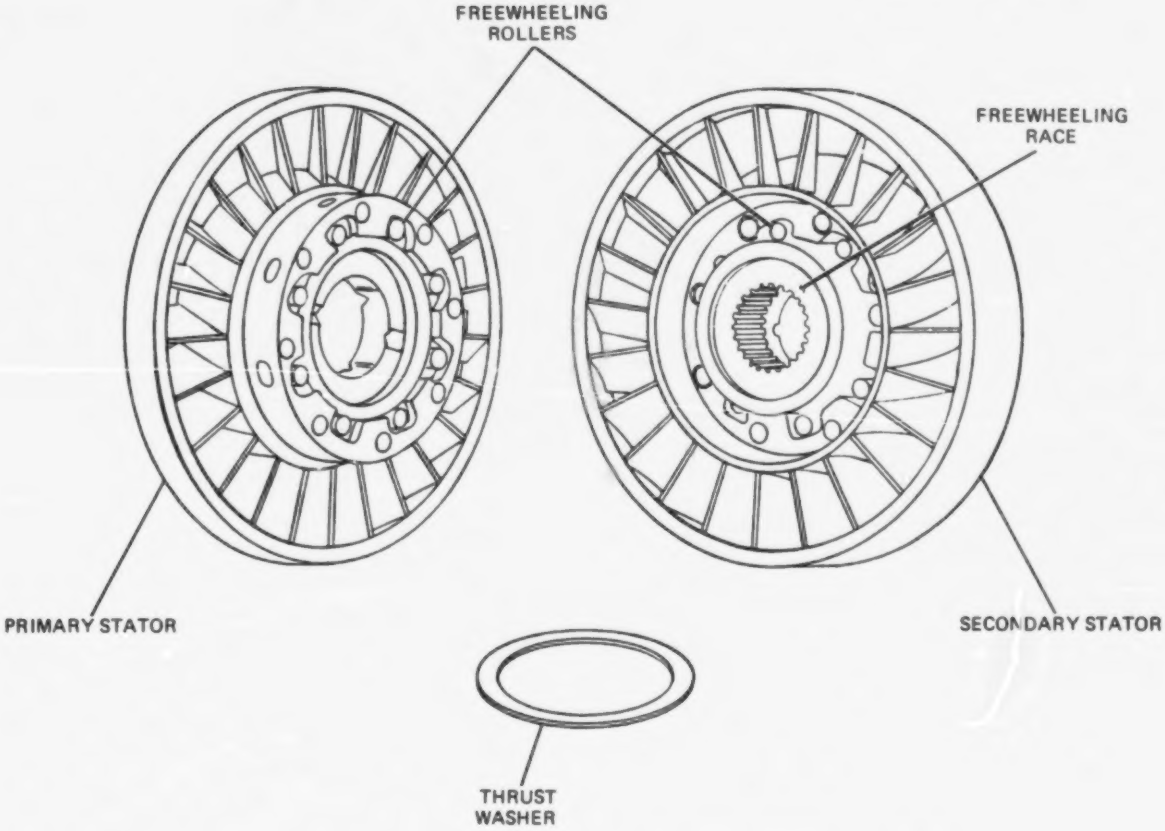


Figure 21-18. Primary and Secondary Stators Showing Freewheeling Rotors.

faces of the secondary pump vanes. The secondary pump stops overrunning and slows to primary pump speed. It now helps the primary pump and the two work together as a unit. Under these conditions, the torque converter functions like a fluid coupling.

g. While the above description covers torque converters generally, some torque converters have more secondary members (aside from the pump and turbine) than others. The unit described is a five-member torque converter, with a pump, turbine, primary stator, secondary stator, and secondary pump. Other torque converters have only four members, while still others have only three. In every case, the added units have the job of reversing the direction of oil movement as the oil leaves the turbine when there is considerable difference in turbine and pump speeds.

h. Because torque converters vary considerably in design, the amount of torque multiplication they can achieve also varies. Practical limits seem to be 5:1. Many torque converters provide satisfactory operation with a much lower torque multiplication (some passenger car units provide less than 2.5:1).

i. Many torque converters have oil coolers. Because the oil is subjected to violent agitation and motion, it becomes hot. The oil cooler acts much like the radiator in liquid-cooling systems. As oil passes through the radiator, it gives up heat and emerges at a lower temperature.

21-9. Lockup Torque Converter (Fig. 21-19). Even at normal highway speeds, there is a certain amount of slippage in the torque converter. Some vehicles have a frictional lockup clutch incorporated in their torque converters to eliminate this

TA233689

428

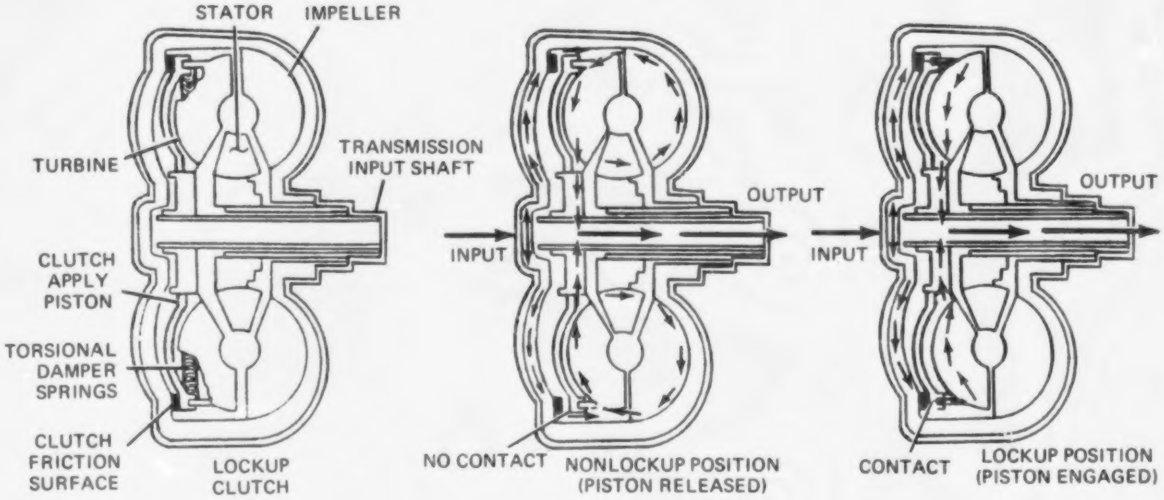

STATOR
IMPELLER
TURBINE
TRANSMISSION INPUT SHAFT
CLUTCH APPLY PISTON
TORSIONAL DAMPER SPRINGS
CLUTCH FRICTION SURFACE
LOCKUP CLUTCH
INPUT
OUTPUT
NO CONTACT
NONLOCKUP POSITION (PISTON RELEASED)
INPUT
OUTPUT
CONTACT
LOCKUP POSITION (PISTON ENGAGED)

Figure 21-19. Torque Converter with Lockup Clutch.

slippage. The principal purpose of the lockup feature is increased gas mileage. Another benefit, however, is increased transmission life through the elimination of the heat caused by torque converter slippage. The lockup unit consists of a friction disk that locks the turbine to the torque converter housing. The friction disk is operated by a hydraulic piston whose pressure is controlled by the automatic transmission control system. The lockup feature usually is designed to operate in high gear at speeds over 35 mph (56 km/h).

TA233690

CHAPTER 22

CONVENTIONAL TRANSMISSIONS

Section I. PURPOSES

22-1. Change Vehicle Direction. One major purpose of the transmission is to provide the operator with the option of maneuvering the vehicle in either the forward or reverse direction. This is a basic requirement of all automotive vehicles. Almost all vehicles have multiple forward gear ratios, but in most cases, only one ratio is provided for reverse.

22-2. Provide Gear Ratio Selection. Another major function of the transmission is to provide the operator with a selection of gear ratios between engine and wheels so that the vehicle can operate at best efficiency under a variety of driving conditions and loads.

Section II. BASIC TYPES

22-3. Sliding Gear. The sliding-gear type is known as the conventional transmission. There are two types of sliding-gear transmissions. One is the progressive, in which the arrangement is such that it is necessary to pass one gear through another in definite order. Thus, in a three-speed progressive transmission, it is impossible to shift from low to high without going through second. The use of this system is limited almost entirely to motorcycles. The other sliding-gear type is known as selective. In this system, the operator can select any ratio without going through intermediate stages. Sliding-gear transmissions use spur gears for easy engagement; consequently, the transmission usually is noisy when operating in the intermediate speeds.

22-4. Constant Mesh. The conventional sliding-gear transmission has been superseded, particularly on passenger vehicles, by systems in which the gears always are in mesh with their mates, and selection is made by sliding components in and out of connection. Two of the most common of these systems are the constant-mesh and the synchromesh, which have additional features to prevent clashing of gears.

Section III. SLIDING GEAR TRANSMISSION

22-5. Construction. Conventional transmissions have the following fundamental components: the case, which houses the gears and shafts; the control cover, which houses the shifter mechanism; and the various shafts and gears. Three-speed selective transmissions have three shafts. They are, in the order of the flow of power, the input shaft, countershaft, and main shaft. The function of the three shafts, together with the gears that connect them, is discussed in detail below.

a. Gears. The transmission second-and-third and first-and-reverse speed main shaft gears have grooved hub extensions, into which the shift forks are fitted that slide them back and forth on the main shaft splines. Thus, the second-and-third speed main shaft gear can be shifted rearward to mesh with the countershaft second-speed gear. The second-and-third speed main shaft gear also has internal teeth that mesh with the external teeth on the rear of the main drive gear when the gear is shifted forward into the direct-drive position. The first-and-reverse speed main shaft gear can be shifted forward to mesh with the countershaft first-speed gear or rearward to mesh with the reverse idler gear. The countershaft reverse gear usually is in constant mesh with the reverse idler gear. In some transmissions, the reverse idler gear is shifted to mesh with the countershaft reverse gear at the same time that the first-and-reverse speed main shaft gear is shifted to mesh with the reverse idler gear.

b. Shafts and Bearings. The input shaft has an integral main drive gear and rotates with the clutch driven plate or disks; that is, the shaft rotates all the time the clutch is engaged and the engine is running. The main drive gear is in constant mesh with the countershaft drive gear. Because all the gears in the countershaft cluster are either made integral or keyed on, they also rotate at the time the clutch is engaged. The transmission main shaft is held in line with the input shaft by a pilot bearing at its front end, which allows it to rotate or come to rest independently of the input shaft. The main shaft, countershaft, and input shafts, with their respective gears, are mounted on antifriction bearings (para 19-8) in the transmission case.

c. *Shift Rails and Forks.* Shift rails and forks are provided to move the gears when the control lever is moved by the driver to change speeds.

22-6. Shifting. The three-speed selective transmission described above is operated by a control lever assembled to, and extending from, the control housing (fig. 22-1). The lever has a ball fulcrum fitting into a socket in the housing. It is kept from rotating by a setscrew entering a slot in the side of the ball fulcrum but is free to move backward, forward, and sidewise. The end of the lever below the ball fulcrum engages both slots, but there is an interlock device (usually a ball or pin engaging notches in each shifter shaft) that permits one shifter shaft to move at a time, but not both. This prevents two speeds being engaged at once. When the control lever handle is pressed to the left, the slot in the first-and-reverse shifter shaft is engaged and the fork can be moved backward or forward. After the first-and-reverse shifter shaft has been returned to the neutral position, the control lever can be pressed to the right and the second-and-third shifter shaft and fork can be moved forward or backward. The shifter shafts are held in the different speeds and the neutral position by spring-loaded balls or poppets engaging notches in the shifter shafts.

22-7. Power Flow. The following paragraphs describe the power flow of the sliding gear transmission.

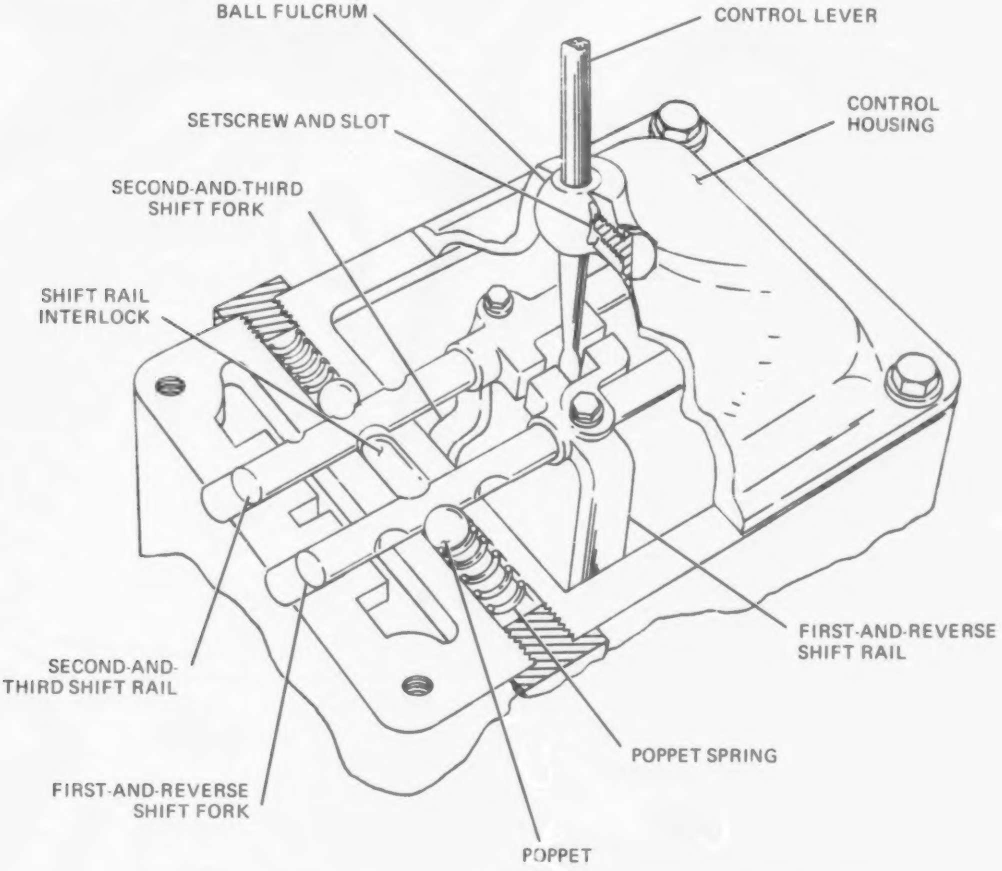

BALL FULCRUM
CONTROL LEVER
SETSCREW AND SLOT
CONTROL HOUSING
SECOND-AND-THIRD SHIFT FORK
SHIFT RAIL INTERLOCK
FIRST-AND-REVERSE SHIFT RAIL
SECOND-AND-THIRD SHIFT RAIL
POPPET SPRING
FIRST-AND-REVERSE SHIFT FORK
POPPET

Figure 22-1. Transmission Shifting Mechanism and Control Lever. TA233691

431

a. Neutral. The gears are shown in the neutral position in figure 22-2. The input shaft drives the countershaft through the main drive gear and countershaft drive gear. None of the countershaft gears are in mesh with the main shaft sliding gears, however, so the main shaft is not driven. When the gears are in this position, there is no connection between the engine and the driving wheels, so the vehicle remains stationary while the engine is running. The path of transmitted power is shown by the arrows.

b. Low Speed. When the gears are in first-speed position, the first-and-reverse speed main shaft gear is shifted forward to mesh with and be driven by the countershaft first-speed gear (fig. 22-3). The countershaft rotates at about 0.7 crankshaft speed. There is a further speed reduction between the countershaft first-speed gear (driving) and the first-and-reverse main shaft gear (driven) of approximately 1.5. Therefore, the crankshaft rotates 1.5 x 1.5, or 2.25 times for each turn of the propeller shaft, thus increasing the torque on the output shaft by 2.25:1.

c. Intermediate Speed. The second-speed position is shown in figure 22-4. In passing from first to second speed, both sliding gears have been shifted rearward; the first-and-reverse speed main shaft gear has been shifted out of engagement into the neutral position and the second-and-third speed main shaft gear has been shifted into mesh with the countershaft second-speed gear. The input shaft, through its integral main drive gear, is now driving the countershaft through the countershaft drive gear (as is the case in all speeds), and the countershaft is driving the main shaft through the countershaft second-speed gear and the second-and-third speed main shaft gear as shown by the arrows (fig. 22-4). Because the countershaft second-speed gear and the second-and-third speed main shaft gear are the same size, their gear ratio is 1:1. This means that the main shaft rotates at the same speed as the countershaft; that is, the engine crankshaft makes about 1.5 revolutions to one of the propeller shaft.

d. High Speed. The third-speed, or direct-drive, position of the gears is shown in figure 22-5. In passing from second speed to third speed, the second-and-third speed main shaft gear has been shifted forward, causing the internal teeth in this gear to engage the external

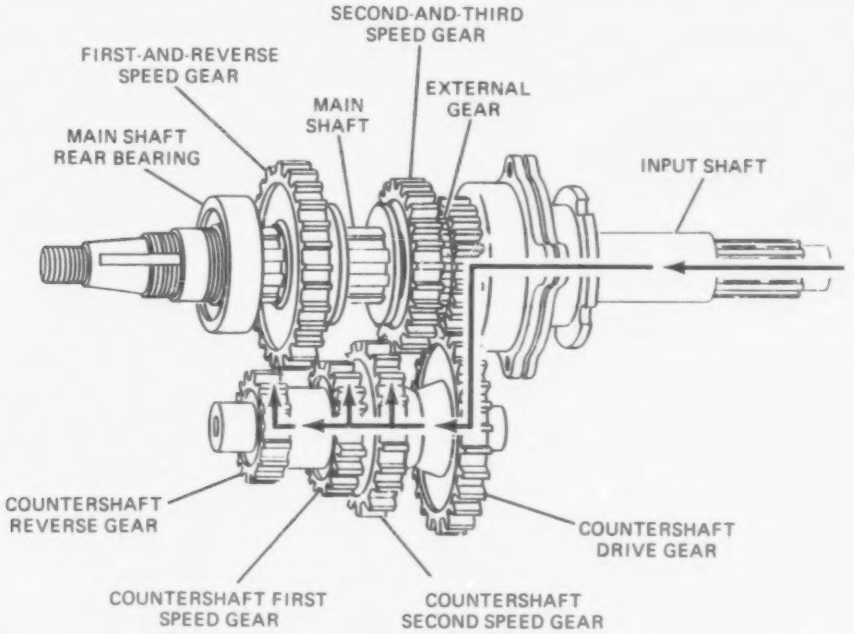

SECOND-AND-THIRD SPEED GEAR
FIRST-AND-REVERSE SPEED GEAR
MAIN SHAFT
EXTERNAL GEAR
MAIN SHAFT REAR BEARING
INPUT SHAFT
COUNTERSHAFT REVERSE GEAR
COUNTERSHAFT DRIVE GEAR
COUNTERSHAFT FIRST SPEED GEAR
COUNTERSHAFT SECOND SPEED GEAR

Figure 22-2. Transmission Gears in Neutral Position.

TA233692

432

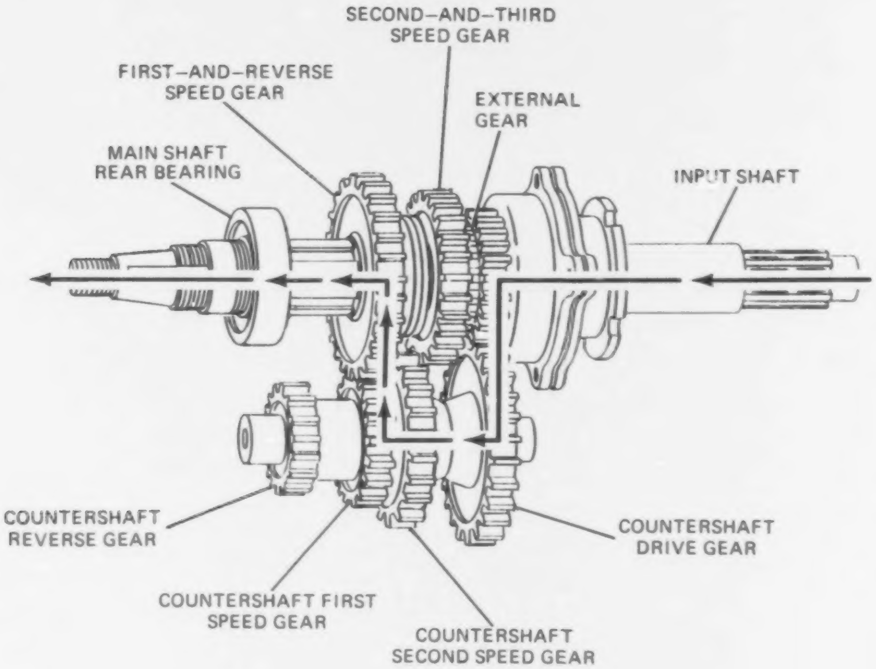

SECOND–AND–THIRD SPEED GEAR
FIRST–AND–REVERSE SPEED GEAR
EXTERNAL GEAR
MAIN SHAFT REAR BEARING
INPUT SHAFT
COUNTERSHAFT REVERSE GEAR
COUNTERSHAFT DRIVE GEAR
COUNTERSHAFT FIRST SPEED GEAR
COUNTERSHAFT SECOND SPEED GEAR

Figure 22-3. Transmission Gears in Low Position.

teeth on the main drive gear. A device of this kind, with internal teeth on one member that mesh or engage with external teeth on another member, is often called a dog clutch, or clutch gear. It makes a direct connection between the input shaft and main shaft as shown by the arrows (fig. 22-5). The propeller shaft therefore rotates at crankshaft speed.

e. Reverse. The reverse position of the gears is shown in figure 22-6. To better illustrate the reverse idler gear, the parts have been turned

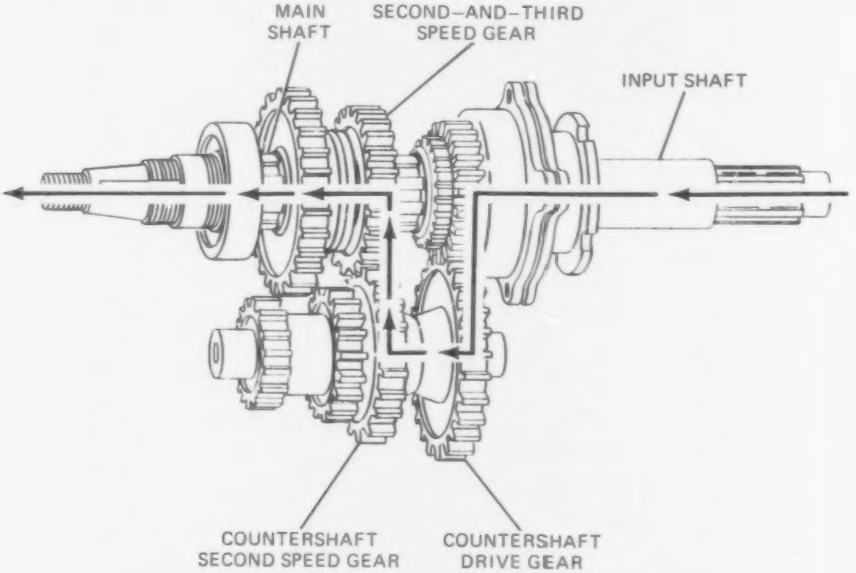

MAIN SHAFT
SECOND–AND–THIRD SPEED GEAR
INPUT SHAFT
COUNTERSHAFT SECOND SPEED GEAR
COUNTERSHAFT DRIVE GEAR

Figure 22-4. Transmission Gears in Intermediate Position.

TA233693

433

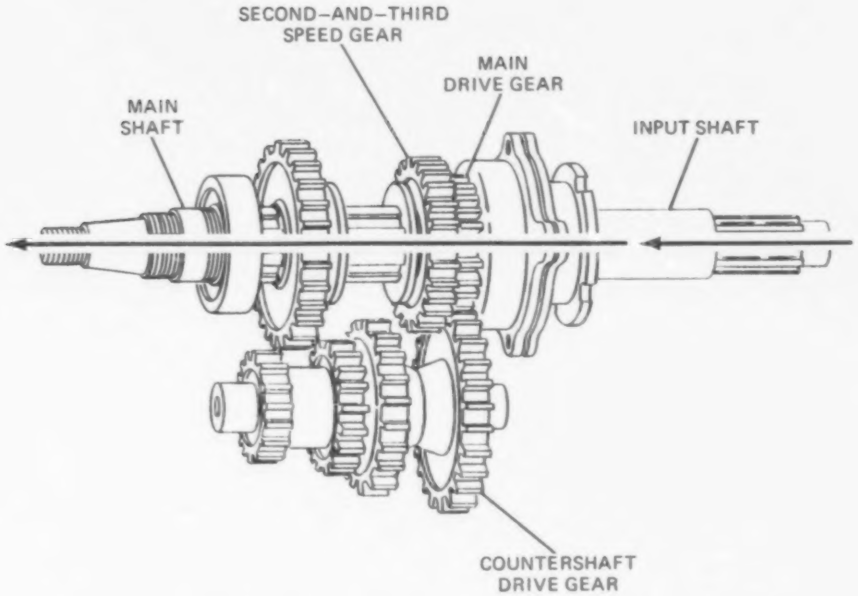

SECOND-AND-THIRD SPEED GEAR
MAIN DRIVE GEAR
MAIN SHAFT
INPUT SHAFT
COUNTERSHAFT DRIVE GEAR

Figure 22-5. Transmission Gears in High Position.

end for end, and are shown from the opposite side from previous illustrations (fig. 22-2 thru 22-5). In passing from neutral to reverse, the first-and-reverse speed main shaft gear has been shifted rearward to mesh with the reverse idler gear. The sole function of this gear is to make the main shaft rotate in the opposite direction to the input shaft; it does not influence the gear ratio between the countershaft reverse gear and the first-and-reverse speed main shaft gear. The gear ratio between these gears is about two. In reverse, the crankshaft rotates 1.5 x 2, or three times for every revolution of the propeller shaft.

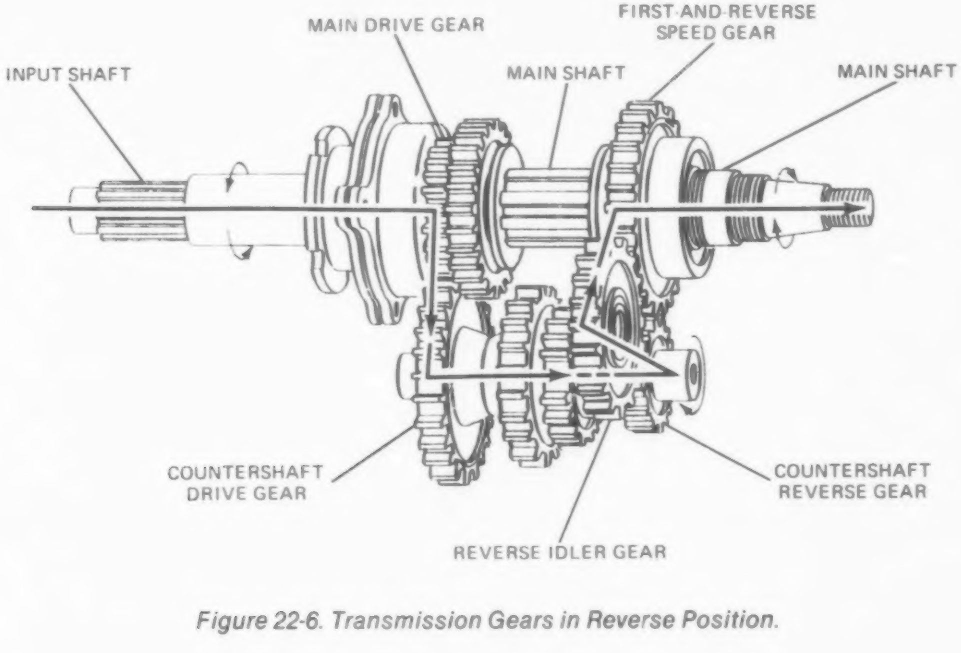

MAIN DRIVE GEAR
FIRST-AND-REVERSE SPEED GEAR
INPUT SHAFT
MAIN SHAFT
MAIN SHAFT
COUNTERSHAFT DRIVE GEAR
COUNTERSHAFT REVERSE GEAR
REVERSE IDLER GEAR

Figure 22-6. Transmission Gears in Reverse Position.

TA233694

232

Section IV. CONSTANT MESH TRANSMISSION

22-8. Construction. The basic components of the constant mesh transmission are similar to the sliding gear transmission discussed in paragraph 22-5. However, major differences in designs are discussed in the following text.

a. Gears. In this type of transmission (fig. 22-7), certain countershaft gears are constantly in mesh with gears on the main shaft. The meshing gears on the main shaft are fixed so they cannot move endwise, but they are supported on roller bearings so they can rotate independently of the main shaft. For example, the main shaft assembly of the transmission shown in figure 22-7 is illustrated in figure 22-8 in disassembled view. Note that the main shaft third-speed gear (4) is supported on the shaft by bearing rollers (5). Note also that this gear has internal teeth that match external teeth on the main shaft third-and-fourth-speed clutch gear (1). Usually, helical gears are used in this type of transmission. The first-reverse-and-second gear (10) is a sliding type and, therefore, is a spur gear.

b. Synchronizers. The construction of a typical synchromesh clutch is shown in figure 22-9. The driving member consists of a sliding gear splined to the transmission main shaft with bronze internal cones on each side. It is surrounded by a sliding sleeve having internal teeth that are meshed with the external teeth of the sliding gear. The sliding sleeve is grooved around the outside to receive the shift fork. Six spring-loaded balls in radially drilled holes in the gear fit into an internal groove in the sliding sleeve and prevent it from moving endwise relative to the gear until the latter has reached the end of its travel. The driven members are the main drive gear and second-speed main shaft gear, each of which has external cones and external teeth machined on its sides to engage the internal cones of the sliding gear and the internal teeth of the sliding sleeve. The synchromesh clutch is shown disengaged and engaged in figure 22-9. The synchromesh clutch operates as follows. When the transmission control lever is moved by the driver to the third-speed or direct-drive position, the shift fork moves the sliding gear and sliding sleeve forward as a unit until the internal cone on the sliding gear engages the external cone on the main drive gear. This action brings the two gears to the same speed and stops endwise travel of the sliding gear. The sliding sleeve then slides over the balls and silently engages the external teeth on the main drive gear, locking the main drive gear and transmission main shaft together as shown in figure 22-9. When the transmission control lever is shifted to the second-speed position, the sliding gear and sleeve move rearward and the same action takes place, locking the transmission main shaft to the second-speed main shaft gear. The synchromesh clutch is not applied to first speed or to reverse. First speed is engaged by an ordinary dog clutch when constant mesh is employed, or by a sliding gear; reverse always is engaged by means of a sliding gear. Figure 22-10 shows a synchromesh transmission in cross section that uses constant-mesh helical gears for the three forward speeds and a sliding spur gear for reverse.

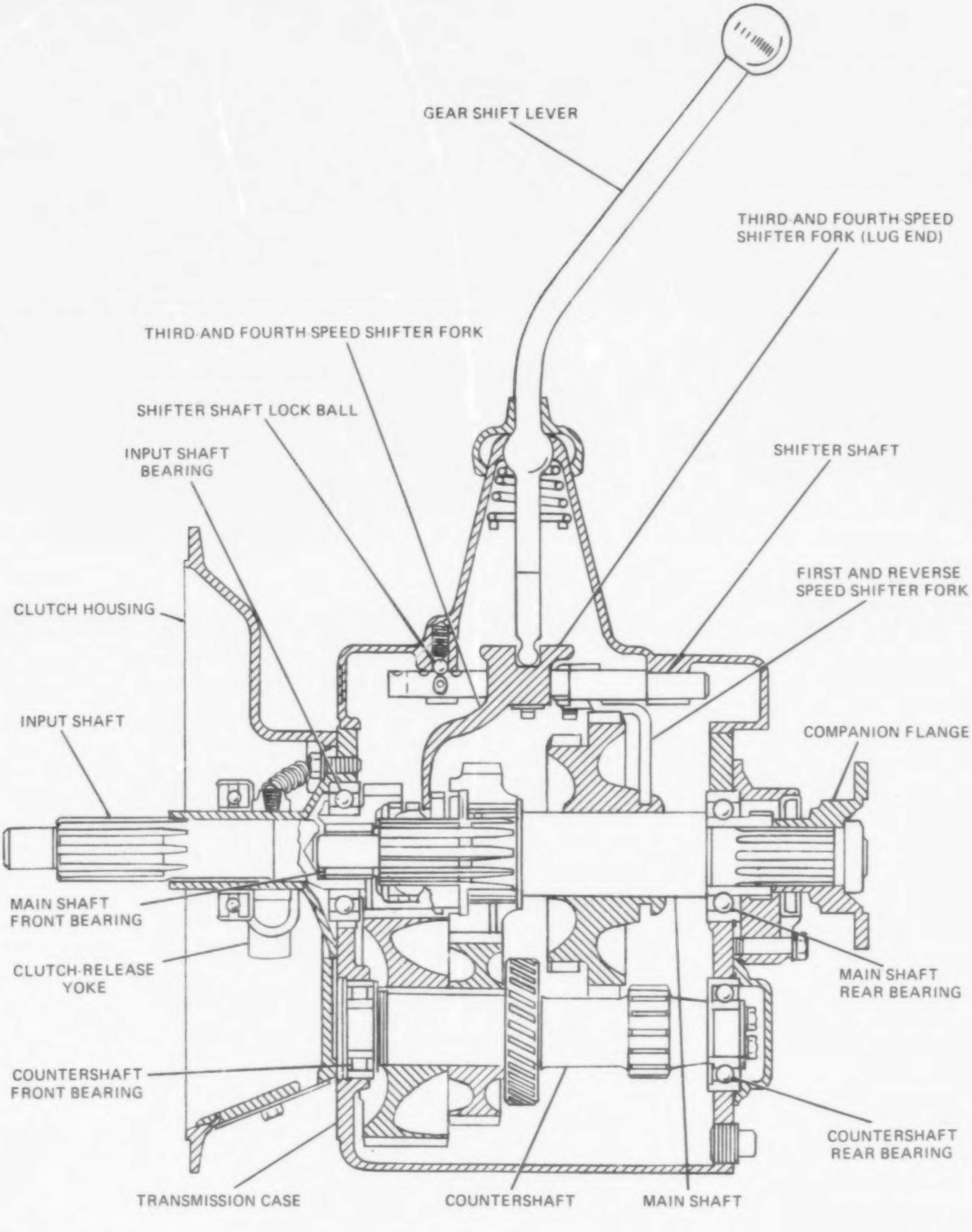
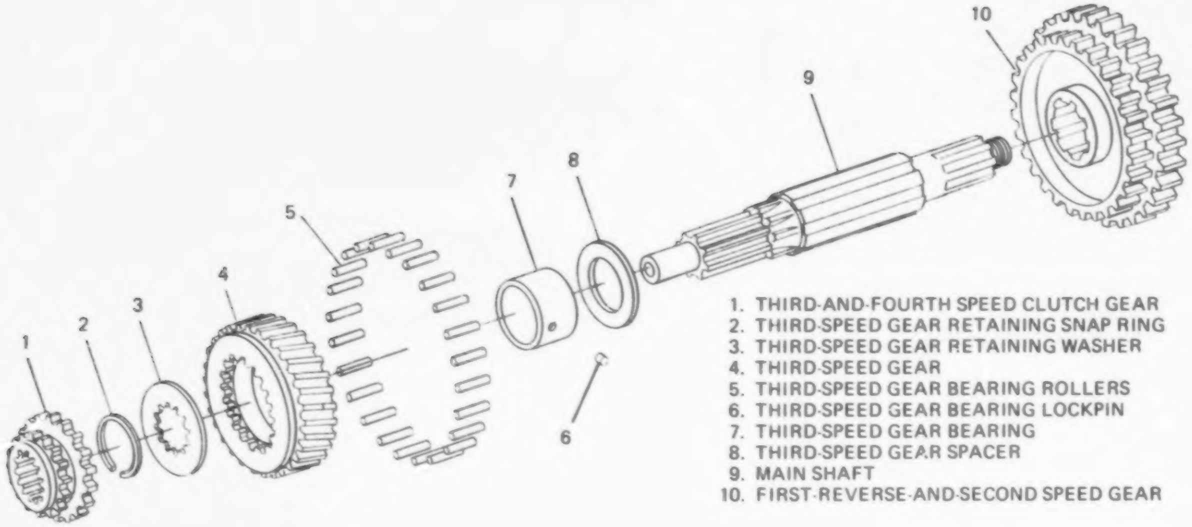

GEAR SHIFT LEVER
THIRD-AND FOURTH-SPEED SHIFTER FORK (LUG END)
THIRD-AND FOURTH-SPEED SHIFTER FORK
SHIFTER SHAFT LOCK BALL
INPUT SHAFT BEARING
SHIFTER SHAFT
FIRST AND REVERSE SPEED SHIFTER FORK
CLUTCH HOUSING
INPUT SHAFT
COMPANION FLANGE
MAIN SHAFT FRONT BEARING
CLUTCH-RELEASE YOKE
MAIN SHAFT REAR BEARING
COUNTERSHAFT FRONT BEARING
COUNTERSHAFT REAR BEARING
TRANSMISSION CASE
COUNTERSHAFT
MAIN SHAFT

Figure 22-7. Constant Mesh Transmission Assembly.

TA233695

436


1
2
3
4
5
6
7
8
9
10

1. THIRD-AND-FOURTH SPEED CLUTCH GEAR
2. THIRD-SPEED GEAR RETAINING SNAP RING
3. THIRD-SPEED GEAR RETAINING WASHER
4. THIRD-SPEED GEAR
5. THIRD-SPEED GEAR BEARING ROLLERS
6. THIRD-SPEED GEAR BEARING LOCKPIN
7. THIRD-SPEED GEAR BEARING
8. THIRD-SPEED GEAR SPACER
9. MAIN SHAFT
10. FIRST-REVERSE-AND-SECOND SPEED GEAR

Figure 22-8. Main Shaft Assembly.

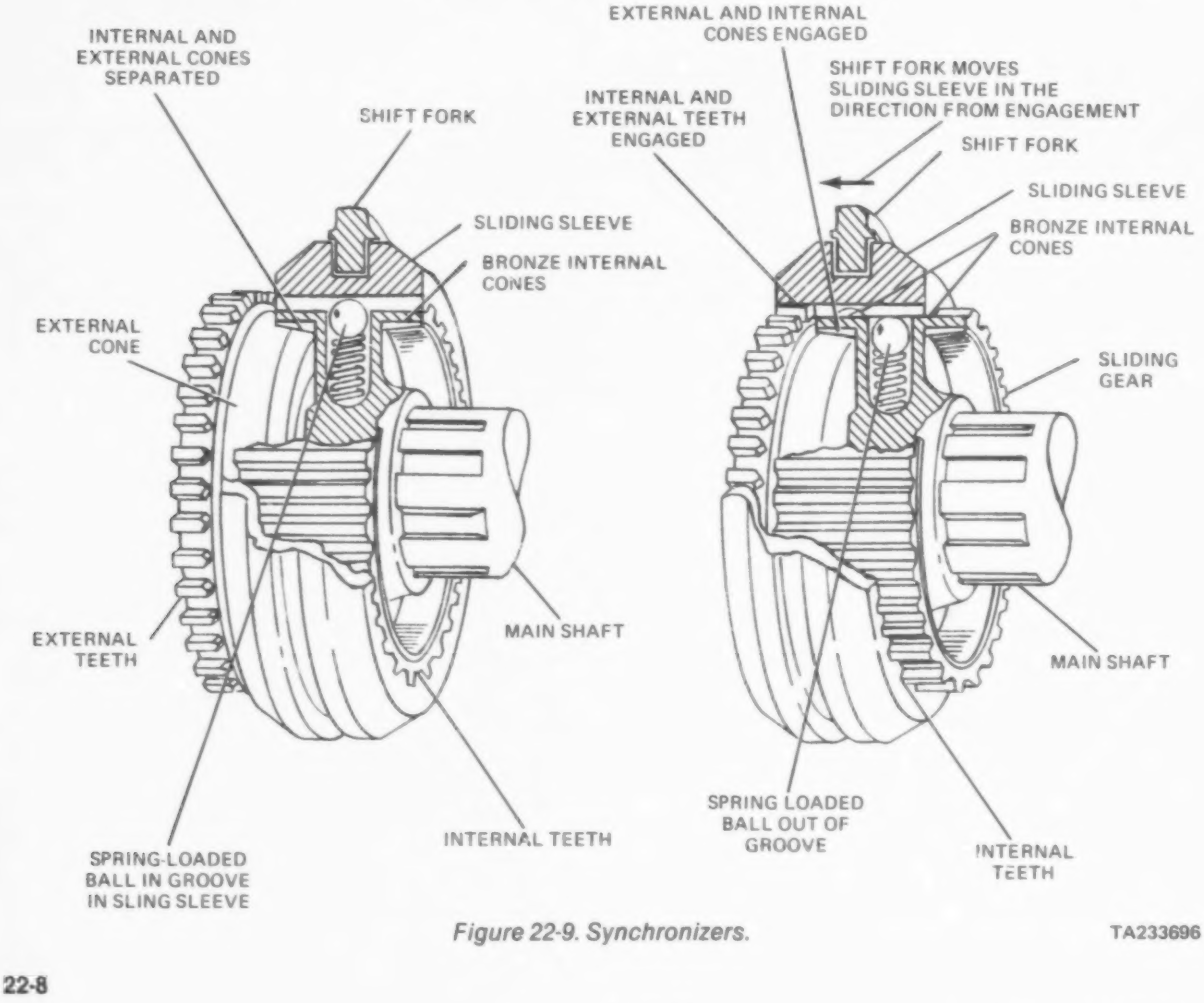

INTERNAL AND EXTERNAL CONES SEPARATED
SHIFT FORK
SLIDING SLEEVE
BRONZE INTERNAL CONES
EXTERNAL CONE
EXTERNAL TEETH
MAIN SHAFT
INTERNAL TEETH
SPRING-LOADED BALL IN GROOVE IN SLING SLEEVE
EXTERNAL AND INTERNAL CONES ENGAGED
INTERNAL AND EXTERNAL TEETH ENGAGED
SHIFT FORK MOVES SLIDING SLEEVE IN THE DIRECTION FROM ENGAGEMENT
SHIFT FORK
SLIDING SLEEVE
BRONZE INTERNAL CONES
SLIDING GEAR
MAIN SHAFT
SPRING LOADED BALL OUT OF GROOVE
INTERNAL TEETH

Figure 22-9. Synchronizers.

TA233696

437

BEST COPY AVAILABLE

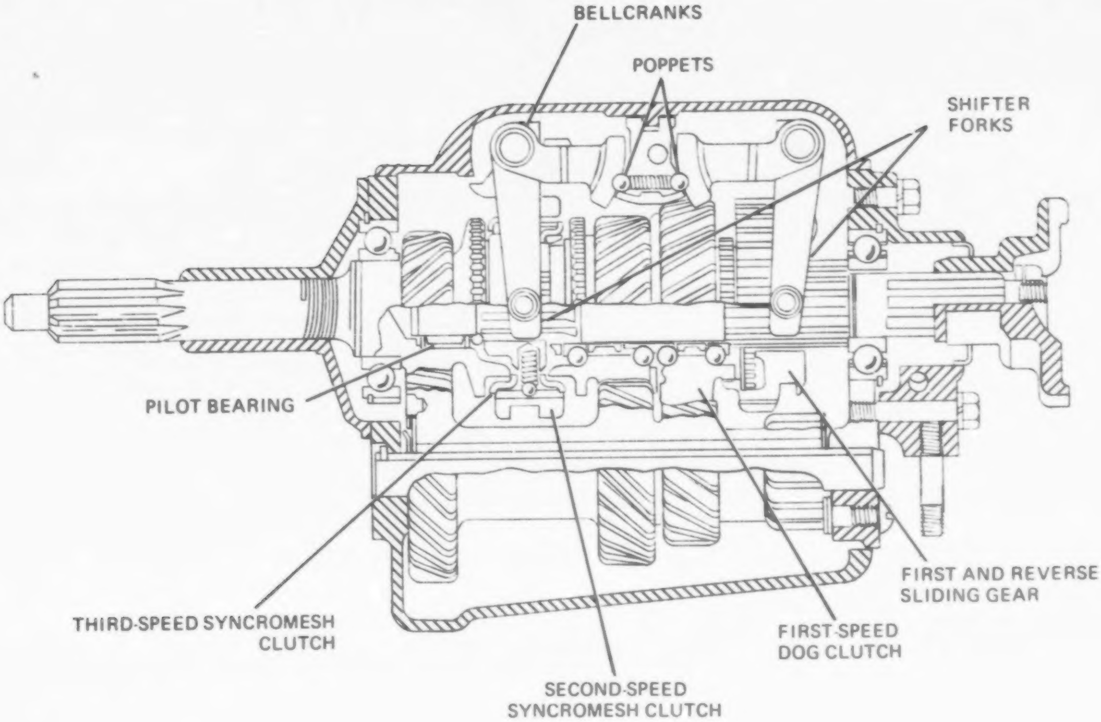

BELLCRANKS
POPPETS
SHIFTER FORKS
PILOT BEARING
FIRST AND REVERSE SLIDING GEAR
THIRD-SPEED SYNCROMESH CLUTCH
FIRST-SPEED DOG CLUTCH
SECOND-SPEED SYNCROMESH CLUTCH

Figure 22-10. Synchromesh Transmission.

Section V. GEARSHIFT LINKAGE

22-9. Mechanical. Some transmissions are controlled by a steering column control lever (fig. 22-11). The positions for the various speeds are the same as those for the vertical control lever except that the lever is horizontal. The shifter forks are pivoted on bellcranks that are turned by a steering column control lever through the linkage shown. The poppets shown in figure 22-11 engage notches at the inner end of each bellcrank. Other types of synchromesh transmissions controlled by steering column levers have shifter shafts and forks moved by a linkage similar to those used with a vertical control lever.

TA233697

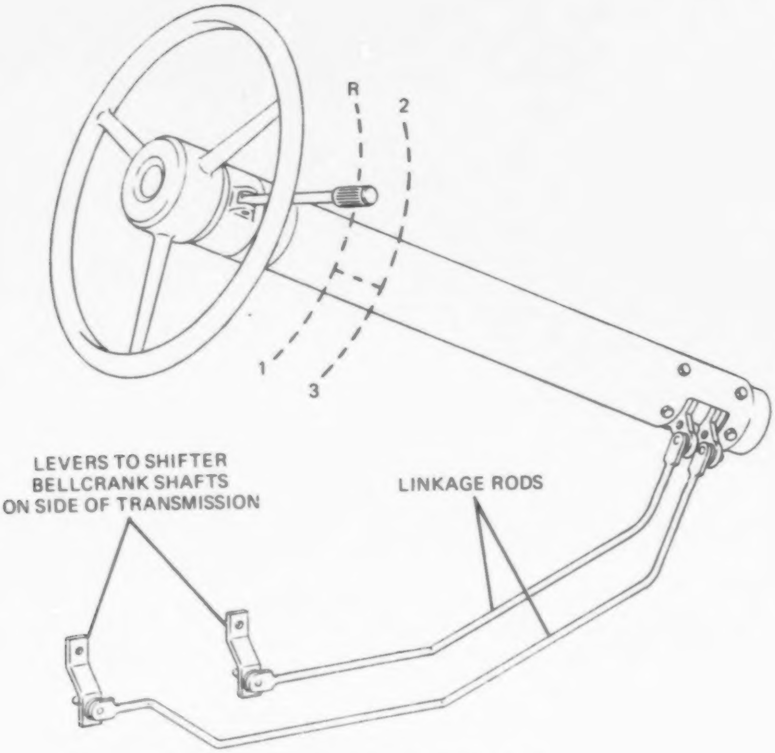

R
2
1
3
LEVERS TO SHIFTER BELLCRANK SHAFTS ON SIDE OF TRANSMISSION
LINKAGE RODS

Figure 22-11. Gearshift Linkage.

TA233698

439

CHAPTER 23

AUTOMATIC TRANSMISSIONS

Section I. GENERAL OPERATION

23-1. Description (Fig. 23-1). The automatic transmission, like the conventional transmission, is designed to match the load requirements of the vehicle to the power and speed range of the engine. The automatic transmission, however, does this automatically depending on throttle position, vehicle speed, and the position of the shift control lever. Automatic transmissions are built in models that have two, three, or four forward speeds and in some that are equipped with overdrive. Operator control is limited to the selection of the gear range by moving a control lever.

23-2. Coupling (Fig. 23-1). The automatic transmission is coupled to the engine through a torque converter (para 21-7). The torque converter is used with an automatic transmission, mainly because it does not have to be manually disengaged by the operator each time the vehicle is stopped. Because the automatic transmission shifts without any interruption of engine torque application, the cushioning effect of the fluid coupling within the torque converter also is desirable.

23-3. Shifting. Because the automatic transmission shifts gear ratios independent of the operator, it must do so without the operator releasing the throttle. The automatic transmission does this by utilizing planetary gearsets whose elements are locked and released in various combinations that produce the required forward and reverse gear ratios. The locking of the planetary gearset elements is done through the use of hydraulically actuated multiple-disk

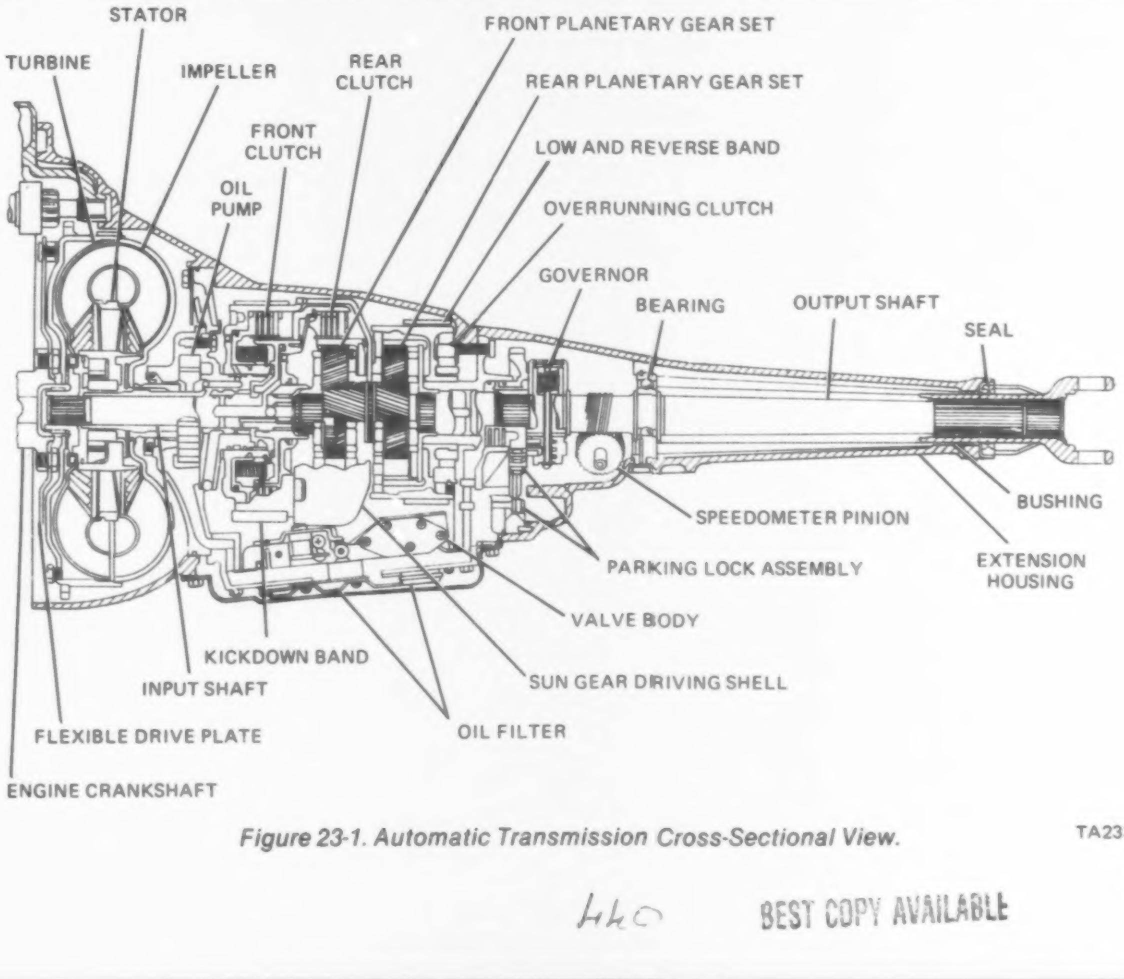

STATOR
TURBINE
IMPELLER
REAR CLUTCH
FRONT PLANETARY GEAR SET
REAR PLANETARY GEAR SET
FRONT CLUTCH
OIL PUMP
LOW AND REVERSE BAND
OVERRUNNING CLUTCH
GOVERNOR
BEARING
OUTPUT SHAFT
SEAL
BUSHING
SPEEDOMETER PINION
PARKING LOCK ASSEMBLY
EXTENSION HOUSING
VALVE BODY
KICKDOWN BAND
INPUT SHAFT
SUN GEAR DRIVING SHELL
FLEXIBLE DRIVE PLATE
OIL FILTER
ENGINE CRANKSHAFT

Figure 23-1. Automatic Transmission Cross-Sectional View.

TA233699

clutches and brake bands. The hydraulic pressure that actuates these locking devices is controlled by the valve body. The valve body can be thought of as a hydraulic computer that receives signals that indicate vehicle speed, throttle position, and gearshift lever position. Based on this information, the valve body sends hydraulic pressure to the correct locking devices to produce the required gear ratios.

23-4. Operator Controls. The only operator control for an automatic transmission is the gearshift lever although the accelerator pedal also can be considered an operator control because it forces the transmission to shift to a lower ratio when it is fully depressed.

Section II. DRIVE TRAIN MECHANISMS

23-5. Multiple-Disk Clutch.

a. General (Fig. 23-2). The multiple-disk clutch, in most cases, is used to transmit torque by locking elements of the planetary gearsets to rotating members within the transmission. In some cases, the multiple-disk clutch also is used to lock a planetary gearset element to the transmission case so that it can act as a reactionary member.

b. Construction (Fig. 23-2). The multiple-disk clutch is comprised of the following components:

(1) *Disks and Plates.* The active components of the multiple-disk clutch are the disks and the plates. The disks are made of steel and are faced with a friction material. They usually have teeth cut into their inner circumference to positively key them to the clutch hub. The plates are

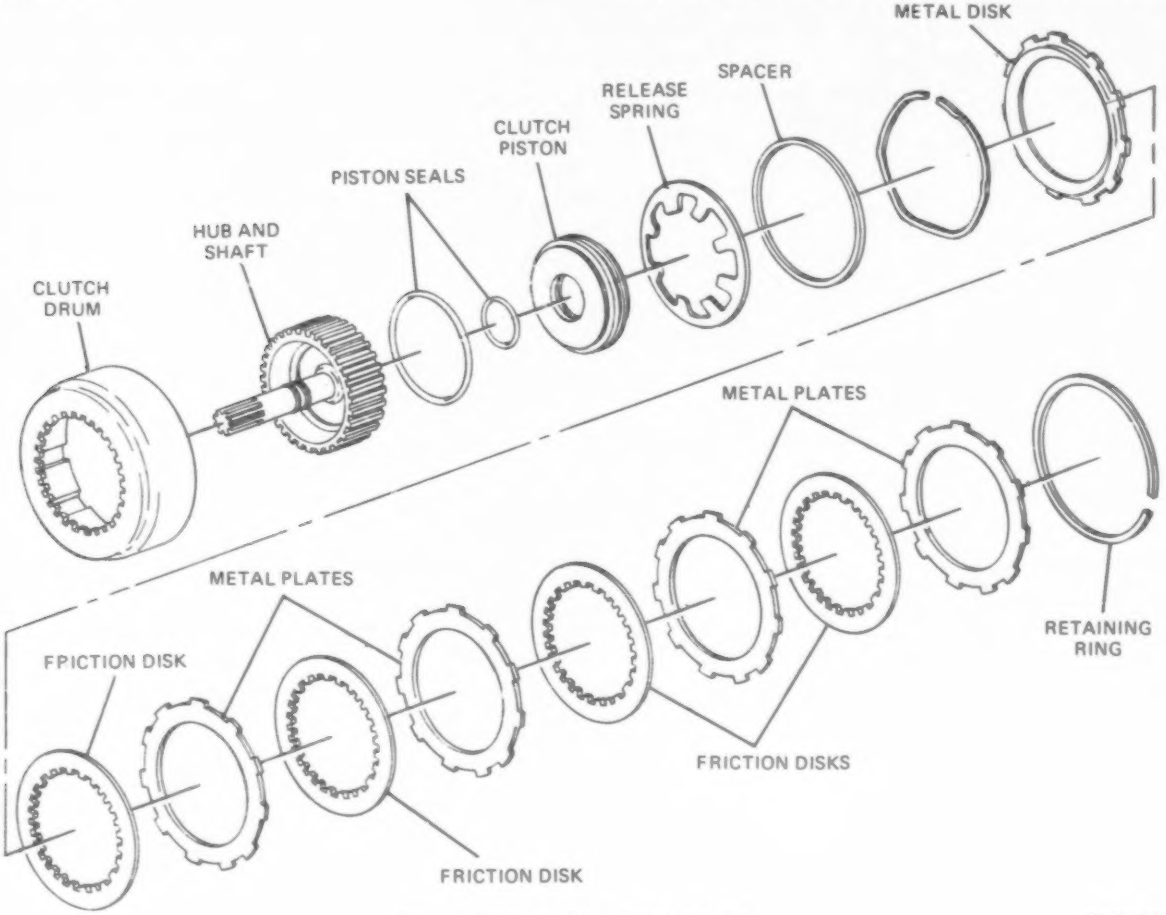

METAL DISK
SPACER
RELEASE SPRING
CLUTCH PISTON
PISTON SEALS
HUB AND SHAFT
CLUTCH DRUM
METAL PLATES
RETAINING RING
METAL PLATES
FRICTION DISK
FRICTION DISKS
FRICTION DISK

Figure 23-2. Multiple-Disk Clutch.

TA233700

made of steel with no facing. They usually have teeth cut into their outer circumference to positively key them inside of a clutch drum or to the inside of the transmission case. By alternately stacking the disks and plates, they are locked together or released by simply squeezing them.

(2) *Clutch Drum and Hub.* The clutch drum holds the stack of disks and plates, and usually is attached to the planetary gearset element that is being driven. The clutch hub usually attaches to the driving member and fits inside of the clutch disks and plates.

(3) *Pressure Plate.* The pressure plates are thick clutch plates that are placed on either end of the stack. Their purpose is to distribute the application pressure equally on the surfaces of the clutch disks and plates.

(4) *Clutch Piston.* The clutch piston uses hydraulic pressure to apply the clutch. Hydraulic pressure usually is supplied to the clutch piston through the center of the rotating member.

(5) *Clutch Piston Seals.* The clutch piston seals serve to prevent the leakage of hydraulic pressure around the inner and the outer circumferences of clutch piston.

(6) *Clutch Springs.* The clutch springs ensure rapid release of the clutch when hydraulic pressure to the clutch piston is released. The clutch springs may be in the form of several coil springs equally spaced around the piston or one large coil spring that fits in the center of the clutch drum. Some models use a diaphragm-type (Belleville) clutch spring.

c. *Operation (Fig. 23-3).*

(1) *Released.* When the clutch is released, there is no hydraulic pressure on the clutch piston and the clutch disks and plates are free to rotate within each other. The result is that the clutch hub rotates freely and does not drive the clutch drum.

(2) *Applied.* When the clutch is applied, hydraulic pressure is applied to the clutch piston which, in turn, applies pressure to the clutch disks and plates, causing them to lock together. The result is that the clutch hub drives the clutch drum through the clutch.

23-6. Brake Band.

a. *General (Fig. 23-4).* The brake band is used to lock a planetary gearset element to the

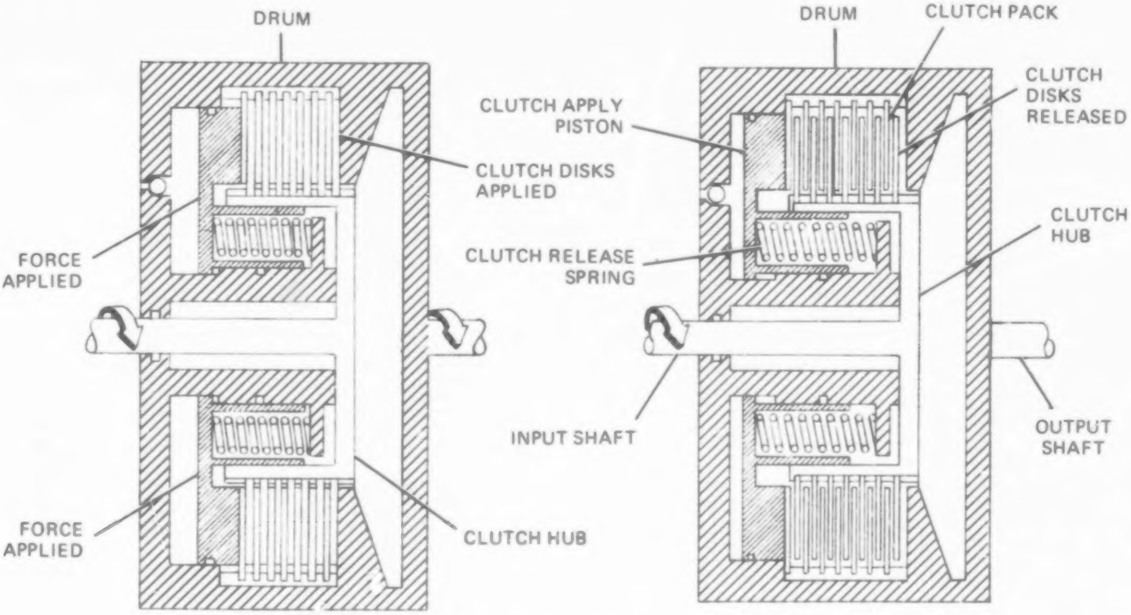


Figure 23-3. Multiple-Disk Clutch Operation.

TA233701

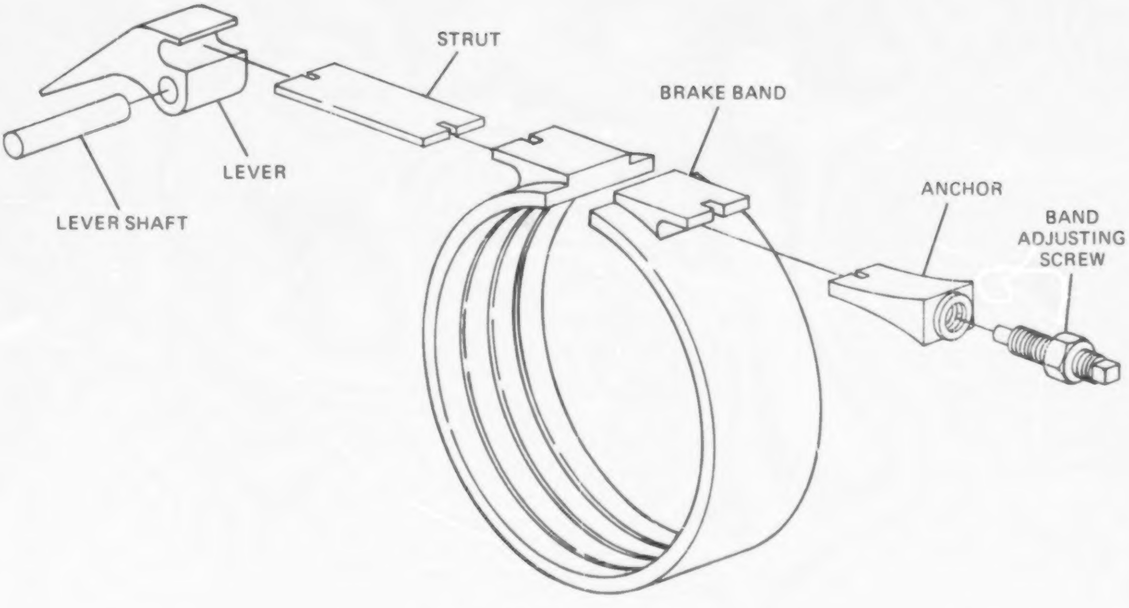


Figure 23-4. Brake Band.

transmission case so that the element can act as a reactionary member.

b. Construction (Fig. 23-5). The brake band is comprised of the following elements:

(1) *Band.* The brake band is a circular piece of spring steel that is rectangular in cross section. Its inside circumference is lined with a friction material. The brake band has bosses on each end so that it can be held and compressed.

(2) *Drum.* The drum fits inside of the band and attaches to the planetary gearset element that is to be locked by the band. Its outer circumference is machined smoothly to interact with the friction surface of the band. By pulling the open ends of the band together, the rotation of the drum stops.

(3) *Anchor.* The anchor firmly attaches one end of the brake band to the transmission case. A provision for adjusting the clearance between the band and the drum usually is provided on the anchor.

(4) *Servo.* The servo uses hydraulic pressure to squeeze the band around the drum. The servo piston is acted on by hydraulic pressure from the valve body that is fed through an internal passage through the case. The servo piston has a seal around it to prevent leakage of hydraulic pressure and is spring loaded to allow quick release of the band. Some servos use hydraulic pressure on both sides of their pistons so that they use hydraulic pressure for both the release and the application of the band.

c. Operation (Fig. 23-5).

(1) *Released.* When the brake band is released, there is no hydraulic pressure applied to the servo and the drum is free to rotate within the band.

(2) *Applied.* When the brake band is applied, hydraulic pressure is applied to the servo which, in turn, tightens the band around the drum. The result is that the drum is locked in a stationary position, causing an output change from the planetary gearset.

23-7. Overrunning (One-Way) Clutch (Fig. 23-6). The overrunning clutch is used in certain automatic transmissions to lock a planetary gearset element to the transmission case so that it can act as a reactionary member. The operation of the overrunning clutch is the same as that of the one used in the torque converter (para 21-7), and it can be of the sprag or roller type. There is no control system necessary for this mechanism.

TA233702

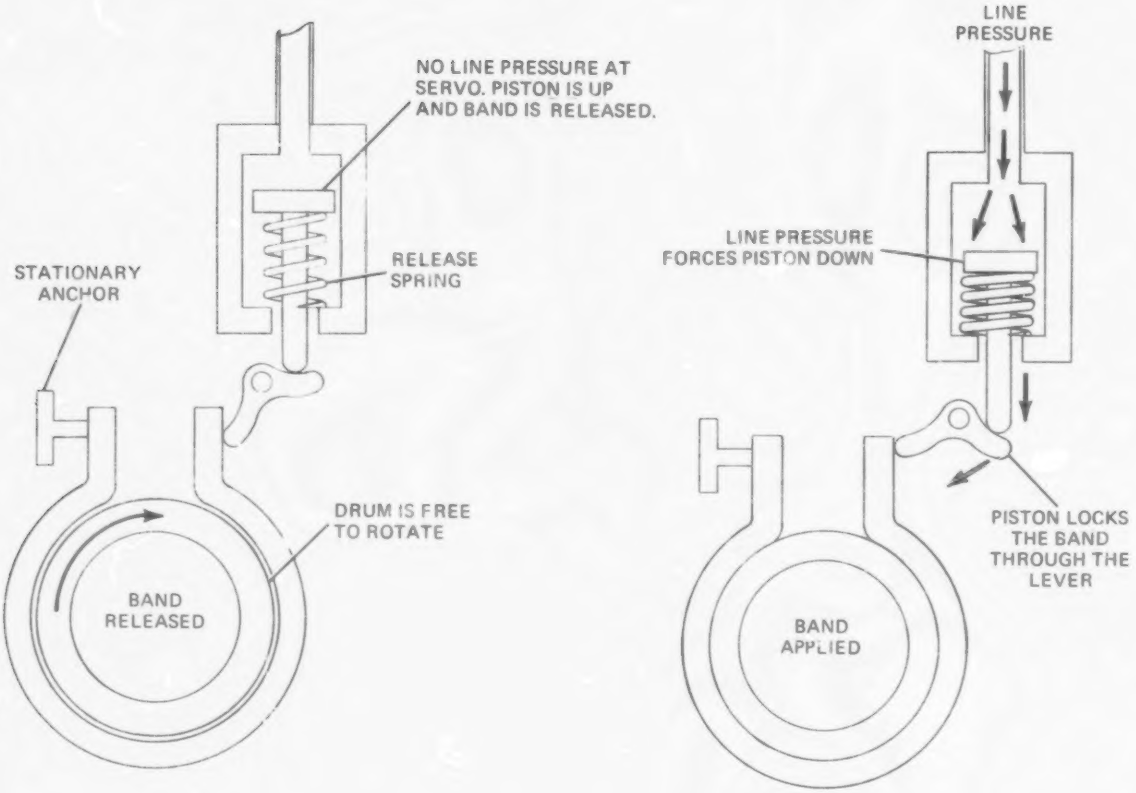

NO LINE PRESSURE AT
SERVO. PISTON IS UP
AND BAND IS RELEASED.
RELEASE
SPRING
STATIONARY
ANCHOR
DRUM IS FREE
TO ROTATE
BAND
RELEASED
LINE
PRESSURE
LINE PRESSURE
FORCES PISTON DOWN
PISTON LOCKS
THE BAND
THROUGH THE
LEVER
BAND
APPLIED

Figure 23-5. Brake Band Operation.

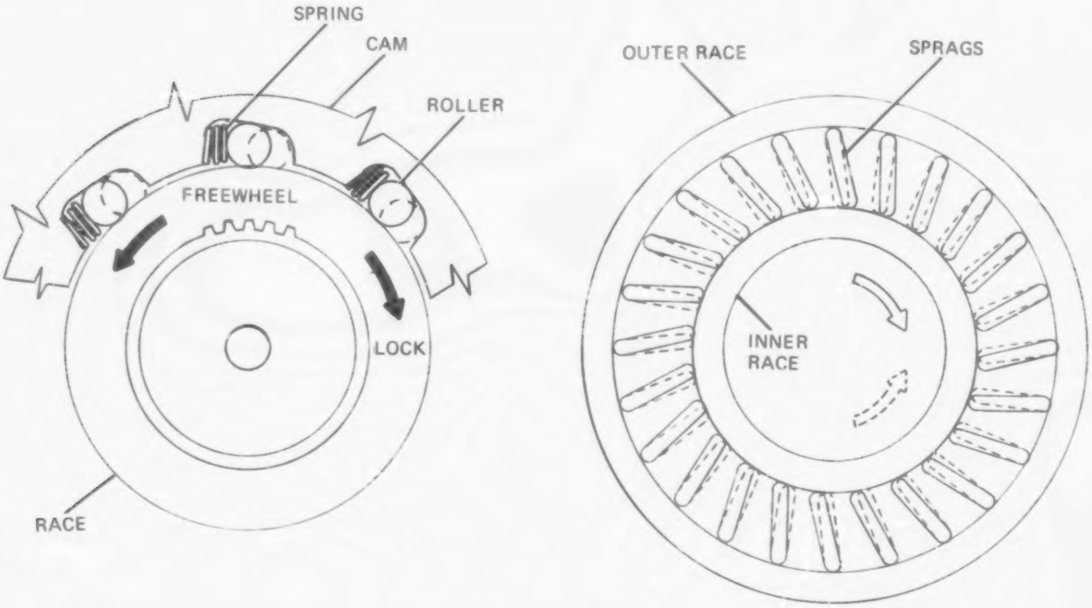

SPRING
CAM
ROLLER
FREEWHEEL
LOCK
RACE
OUTER RACE
SPRAGS
INNER
RACE

Figure 23-6. Overrunning Clutches.

TA233703

Lihh

Section III. DRIVE TRAIN ARRANGEMENTS

23-8. General. Automatic transmissions are built with two, three, and four forward speeds and, therefore, utilize many variations of drive train arrangements. The following paragraphs describe the two most popular arrangements: the compound planetary drive train and the simpson drive train.

23-9. Compound Planetary Drive Train.

a. General (Fig. 23-7). This arrangement combines two multiple-disk clutches and one brake band with a compound planetary gearset. The compound planetary gearset is really two gearsets that are integrated together through the use of long and short pinions. Because of the compactness of this unit, it has all but superseded earlier two-speed drive trains that utilized two separate planetary gearsets.

b. Operation (Fig. 23-8). The compound planetary drive train provides two forward speeds, reverse, and neutral. Power flow in the different gear ranges are as follows:

(1) *Neutral.* When the gearshift lever is placed in neutral, the clutch and brake bands are released. Because of this there is no reactionary member in the planetary gearset to provide positive drive. Therefore, no torque is transmitted to the output shaft as all of the planetary gearset elements are free to spin around their axes.

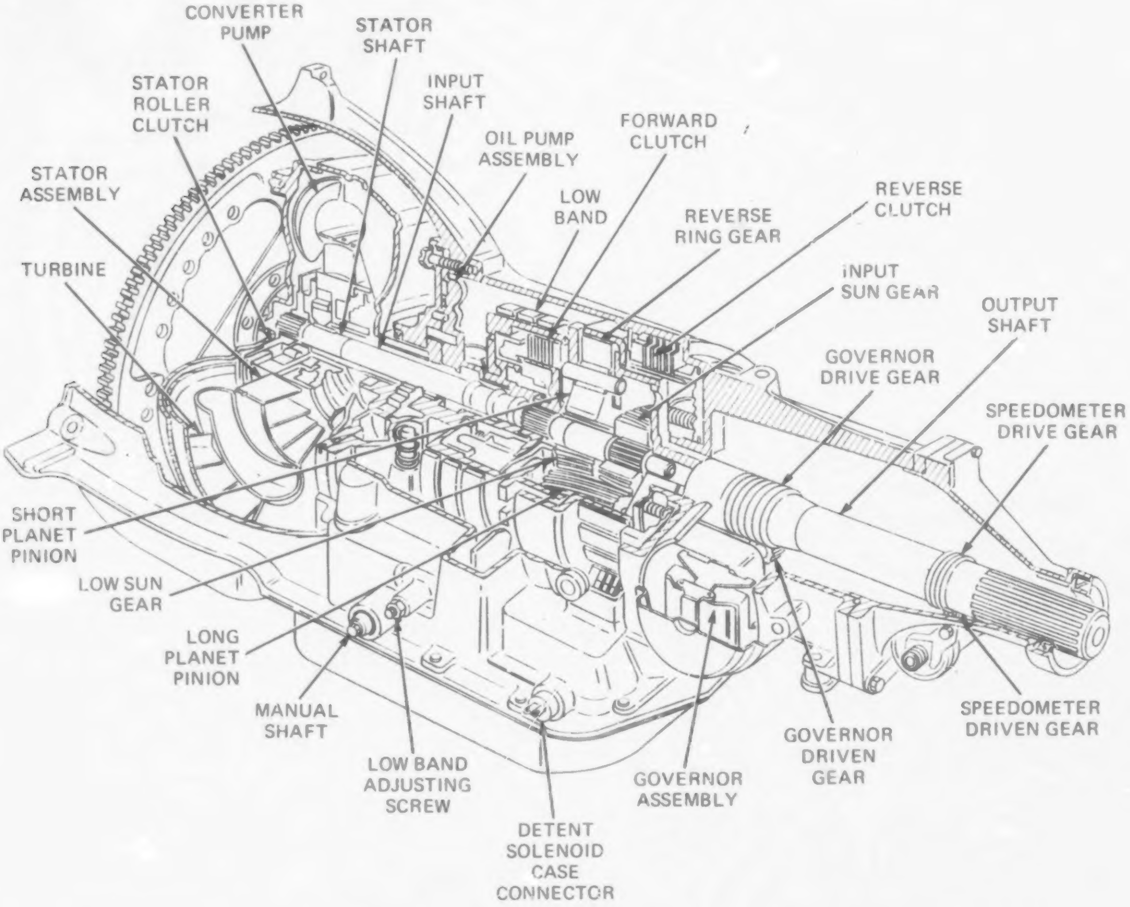
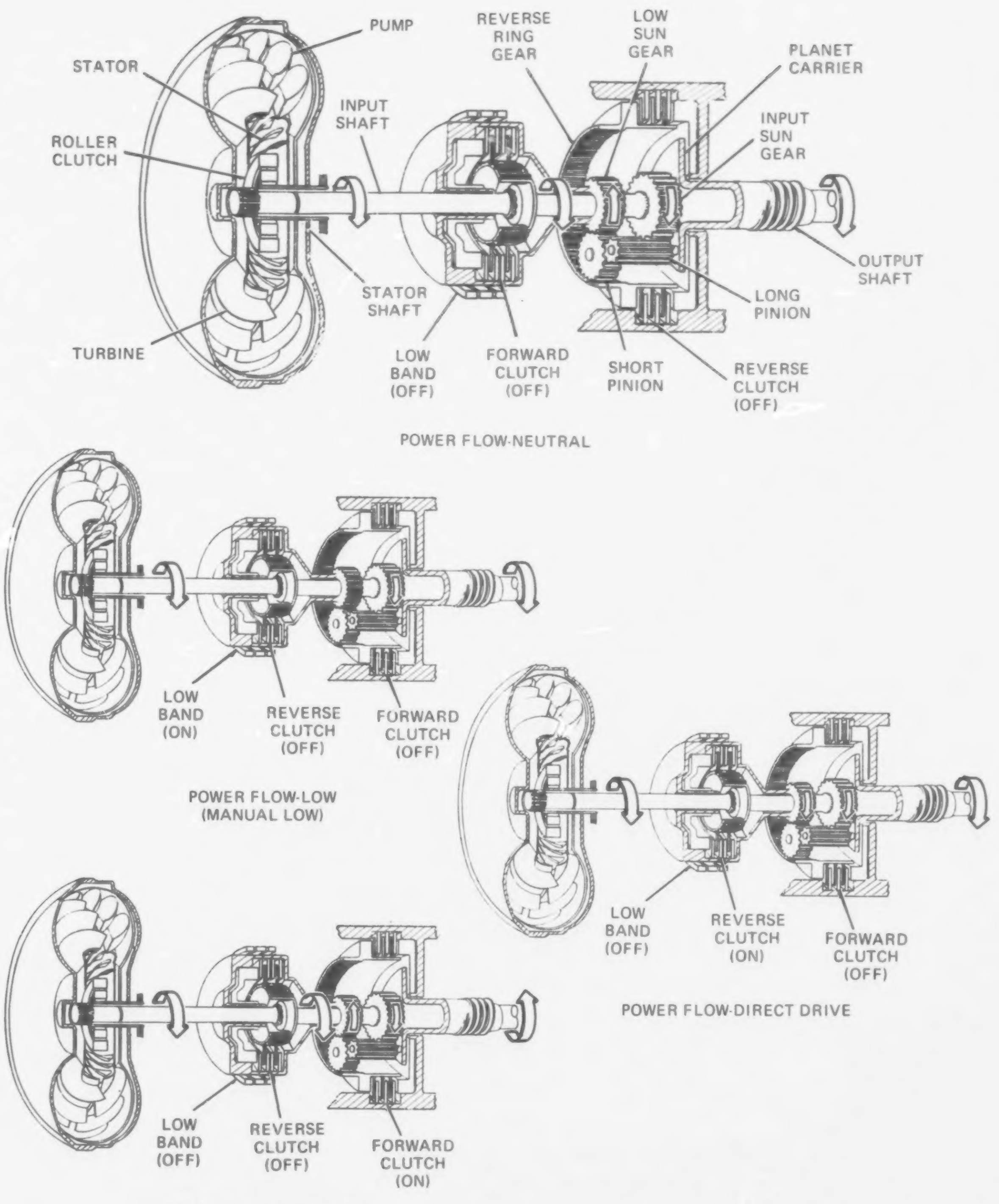

CONVERTER PUMP
STATOR SHAFT
STATOR ROLLER CLUTCH
INPUT SHAFT
OIL PUMP ASSEMBLY
FORWARD CLUTCH
STATOR ASSEMBLY
LOW BAND
REVERSE RING GEAR
REVERSE CLUTCH
TURBINE
INPUT SUN GEAR
OUTPUT SHAFT
GOVERNOR DRIVE GEAR
SPEEDOMETER DRIVE GEAR
SHORT PLANET PINION
LOW SUN GEAR
LONG PLANET PINION
MANUAL SHAFT
LOW BAND ADJUSTING SCREW
DETENT SOLENOID CASE CONNECTOR
GOVERNOR ASSEMBLY
GOVERNOR DRIVEN GEAR
SPEEDOMETER DRIVEN GEAR

Figure 23-7. Typical Two-Speed Automatic Transmission Utilizing Compound Planetary Drive Train.

TA233932


PUMP
STATOR
ROLLER CLUTCH
INPUT SHAFT
REVERSE RING GEAR
LOW SUN GEAR
PLANET CARRIER
INPUT SUN GEAR
OUTPUT SHAFT
LONG PINION
STATOR SHAFT
TURBINE
LOW BAND (OFF)
FORWARD CLUTCH (OFF)
SHORT PINION
REVERSE CLUTCH (OFF)

POWER FLOW-NEUTRAL

LOW BAND (ON)
REVERSE CLUTCH (OFF)
FORWARD CLUTCH (OFF)

POWER FLOW-LOW (MANUAL LOW)

LOW BAND (OFF)
REVERSE CLUTCH (ON)
FORWARD CLUTCH (OFF)

POWER FLOW-DIRECT DRIVE

LOW BAND (OFF)
REVERSE CLUTCH (OFF)
FORWARD CLUTCH (ON)

POWER FLOW-REVERSE

Figure 23-8. Compound Planetary Drive Train Operation.

TA233704

L46

(2) *Low.* When the gearshift lever is placed in low, the direct and reverse clutches are released and the low brake band is applied, locking the low sun gear. Power flow through the drive train is as follows:

(a) From the input sun gear to the long planetary pinions.

(b) From the long planetary pinions to the short planetary pinions.

(c) The locked sun gear then provides a reaction point so that the planetary pinions and carrier can walk around it, rotating the output shaft.

The result is a speed reduction ratio from the input shaft to the output shaft of about 1.8:1. The low-gear power flow also is used when the gearshift lever is in the drive position before the vehicle attains sufficient speed for the transmission to shift to direct drive.

(3) *Direct Drive.* When the gearshift lever is placed in drive, the transmission is in low gear until the vehicle reaches a speed sufficient to allow the transmission to automatically shift to direct drive. The shift to direct drive releases the low brake band and applies the direct clutch, locking the low sun gear to the input shaft. The reverse clutch remains released. Power flow through the drive train is as follows:

(a) From the input sun gear to the long planetary pinions.

(b) From the long planetary pinions to the short planetary pinions.

(c) Because the input and low sun gears are both locked, the planetary pinions are locked and unable to rotate. This forces the planetary carrier and the attached output shaft to rotate at a 1:1 ratio with the input shaft.

(4) *Reverse.* When the gearshift lever is placed in reverse, the low brake band and the direct clutch are released. The reverse clutch is applied, locking the internal gear of the planetary gearset. Power flow through the drive train is as follows:

(a) From the input sun gear to the long planetary pinions.

(b) From the long planetary pinions to the short planetary pinions.

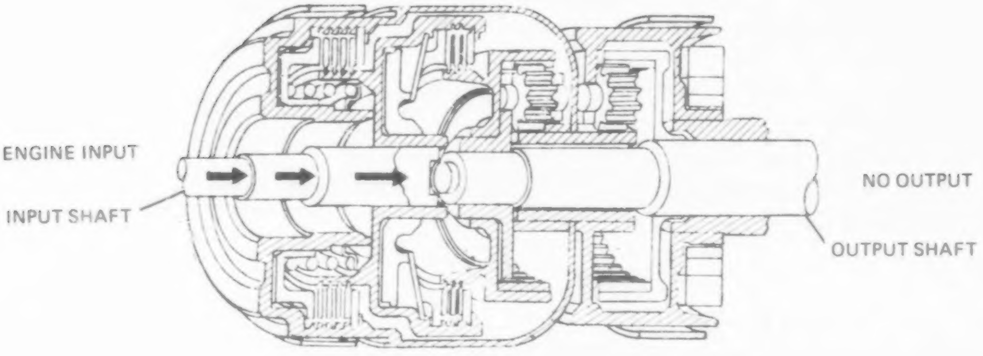
(c) The short planetary pinions walk around the inside of the locked internal gear, rotating the planetary carrier and the attached output shaft in the opposite direction of the input shaft. The speed reduction ratio of the input to the output shafts is approximately 1.8:1.

23-10. Simpson Drive Train.

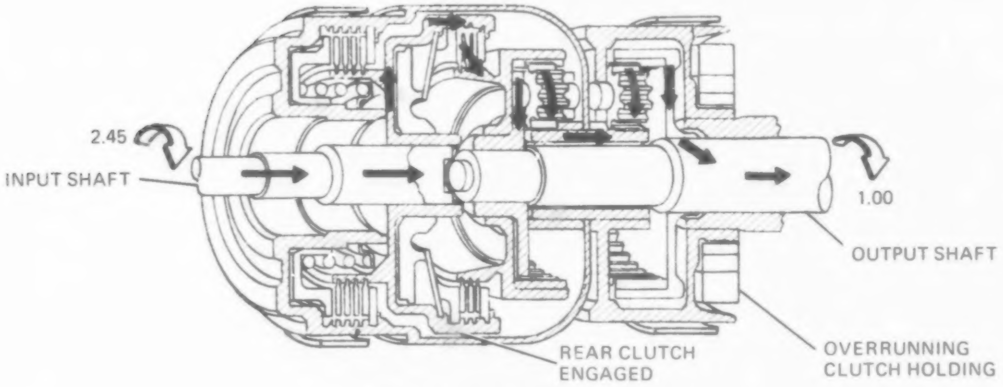
a. General (Fig. 23-9). This arrangement combines two multiple-disk clutches, two brake bands, an overrunning clutch, and two planetary gearsets operating on a common sun gear. The simpson drive train is the standard for virtually all three-speed automatic transmissions that are currently produced.

b. Operation (Fig. 23-9). The simpson drive train provides three forward speeds, reverse, and neutral. Power flow is outlined by the following chart and accompanying text.

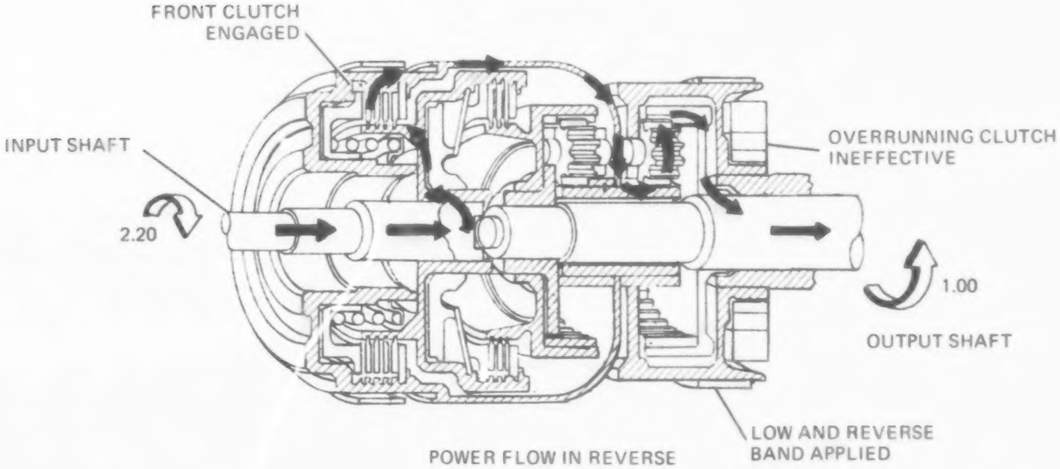
RANGE	GEAR	FRONT CLUTCH	REAR CLUTCH	KICKDOWN BAND	LOW-REVERSE BAND	OVERRUNNING CLUTCH
Reverse		on	off	off	on	no movement
Neutral		off	off	off	off	no movement
D-drive	first	off	on	off	off	holds
	second	off	on	on	off	overruns
	third	on	on	off	off	overruns
2-drive	second	off	on	on	off	overruns
	first	off	on	off	off	holds
1-low	first	off	on	off	on	holds


ENGINE INPUT
INPUT SHAFT
NO OUTPUT
OUTPUT SHAFT

POWER FLOW IN NEUTRAL


2.45
INPUT SHAFT
1.00
OUTPUT SHAFT
REAR CLUTCH ENGAGED
OVERRUNNING CLUTCH HOLDING

POWER FLOW IN BREAKAWAY


FRONT CLUTCH ENGAGED
INPUT SHAFT
2.20
OVERRUNNING CLUTCH INEFFECTIVE
1.00
OUTPUT SHAFT
LOW AND REVERSE BAND APPLIED

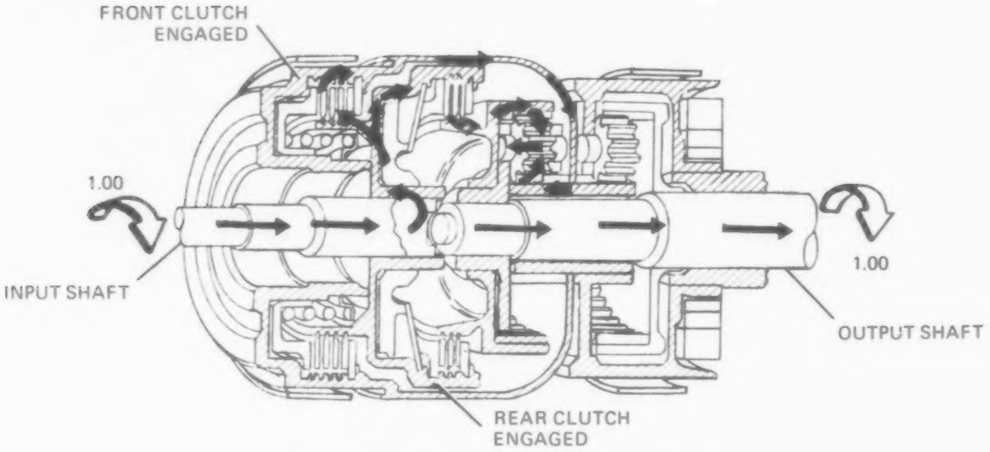
POWER FLOW IN REVERSE

Figure 23-9. Simpson Drive Train Operation. (Part A)

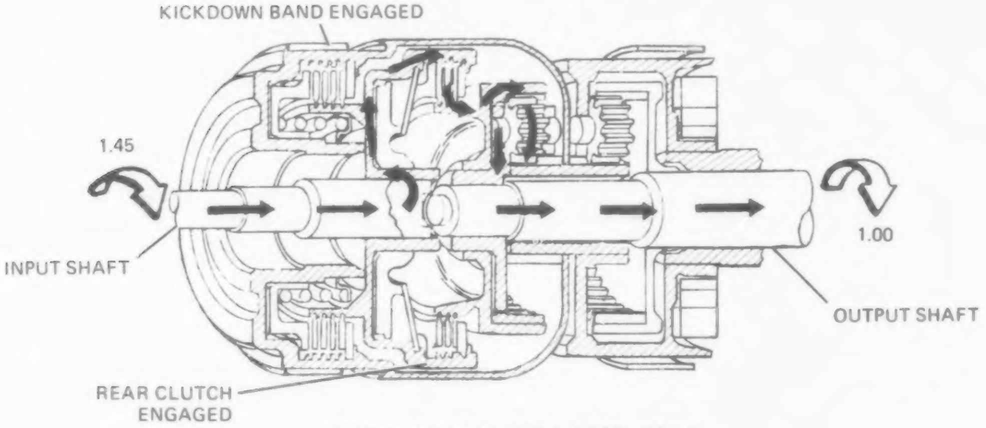
TA233705

448

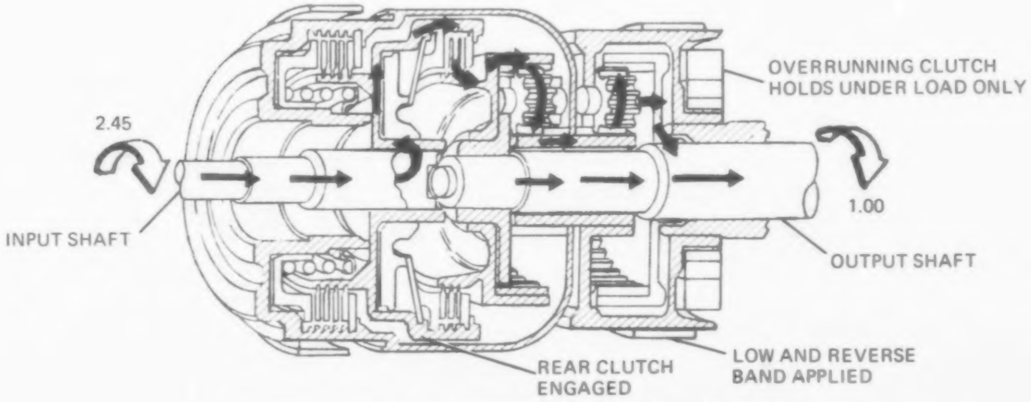
BEST COPY AVAILABLE


FRONT CLUTCH ENGAGED
1.00
INPUT SHAFT
1.00
OUTPUT SHAFT
REAR CLUTCH ENGAGED

POWER FLOW IN D(DRIVE) POSITION - DIRECT


KICKDOWN BAND ENGAGED
1.45
INPUT SHAFT
1.00
OUTPUT SHAFT
REAR CLUTCH ENGAGED

POWER FLOW IN SECOND GEAR - DRIVE


OVERRUNNING CLUTCH HOLDS UNDER LOAD ONLY
2.45
INPUT SHAFT
1.00
OUTPUT SHAFT
REAR CLUTCH ENGAGED
LOW AND REVERSE BAND APPLIED

POWER FLOW IN 1 (LOW) POSITION - LOW OR RETARDING

Figure 23-9. Simpson Drive Train Operation. (Part B)

TA233706

(1) *Neutral.* When the gearshift lever is placed in neutral, the clutch and brake bands are released. The input shaft rotates freely and no torque is transmitted to the output shaft.

(2) *Drive-Low.* When the gearshift lever is placed in drive, the automatic transmission will be in low gear when the vehicle is in a speed range of zero to approximately eight miles per hour. In drive-low the rear clutch is engaged, locking the input shaft to the internal gear of the front planetary gearset. Power flow through the drive train is as follows:

(a) From the input shaft to the internal gear of the front planetary gearset.

(b) From the internal gear to the pinions of the front planetary gearset.

(c) Because the front planetary carrier is locked to the output shaft, it cannot rotate backwards and therefore acts as a reactionary member. This causes the planetary pinions to drive the sun gear.

(d) The sun gear, which is common to both planetary gearsets, then drives the rear planetary pinions.

(e) The rear planetary carrier, which is locked to the transmission case by the overrunning clutch, serves as a reactionary member. The rear planetary pinions, therefore, drive the rear planetary internal gear and the attached output shaft at a speed reduction ratio of approximately 2.45:1.

(3) *Drive-Second.* When the gearshift lever is in drive and the vehicle is between approximately 8 to 20 miles per hour, the transmission normally will be in second gear. In second gear the rear clutch is applied, locking the input shaft to the internal gear of the front planetary gearset. The front brake band also is engaged, locking the sun gear stationary. Power flow through the drive train is as follows:

(a) From the input shaft to the internal gear of the front planetary gearset.

(b) From the internal gear to the pinions of the front planetary gearset.

(c) Because the sungear is locked, it acts as a reactionary member. This causes the planetary pinions to walk around it and rotate the front planetary carrier, which drives the attached output shaft.

(4) *Direct Drive.* When the gearshift lever is in drive and vehicle speed is above approximately 25 miles per hour, the automatic transmission normally is in direct drive. In direct drive, both the front and rear clutches are applied, which ultimately results in the locking of the internal gear to the internal gear in the front planetary gearset. This results in the planetary gears being locked and the whole planetary gearset and the attached output shaft rotating at a 1:1 speed ratio with the input shaft.

(5) *Low.* When the gearshift lever is placed low, the power flow through the drive train is identical to that of drive-low described above. The only difference is the use of the rear brake band rather than the overrunning clutch to lock the carrier of the rear planetary gearset. Because the rear brake band prevents the element from rotating in either direction, the drive train is able to provide engine braking during vehicle deceleration with the transmission in low. This contrasts with drive-low, which allows the vehicle to freewheel during deceleration due to the one-way locking of the overrunning clutch.

(6) *Reverse.* When the gearshift lever is in reverse, the front clutch is applied, locking the sun gear to the input shaft. The rear brake band also is applied, holding the carrier of the rear planetary gearset stationary. Power flow through the drive train is as follows:

(a) From the input shaft to the sun gear.

(b) From the sun gear to the rear planetary pinions.

(c) Because the rear planetary carrier is held stationary, it acts as a reactionary member. The rear planetary pinions, therefore, drive the internal gear of the rear planetary gearset and the attached output shaft in reverse rotation to the input shaft at a speed reduction ratio of approximately 2.2:1.

L1 50

Section IV. HYDRAULIC SYSTEM

23-11. Purposes. The hydraulic system serves four basic purposes:

a. The planetary holding devices (clutches and brake bands) are all actuated by hydraulic pressure from the hydraulic slave circuits.

b. The shifting pattern of the transmission is controlled by the hydraulic system. This is done by switching hydraulic pressure to programmed combinations of the planetary holding devices based on vehicle speed and engine load indicators.

c. The hydraulic system circulates the oil through a remote cooler to remove excess heat that is generated in the transmission and torque converter.

d. The hydraulic system provides a constant fresh supply of oil to all critical wearing surfaces of the transmission.

23-12. Supply System (Fig. 23-10). The supply system provides a clean pressure-regulated supply of oil for the hydraulic system of the automatic transmission. Early automatic transmissions used a combination of an engine-driven pump that worked in conjunction with an output shaft-driven pump. This configuration no longer is used and, therefore, will not be covered. The operation and construction of a typical system is described below.

a. Hydraulic Pump (Fig. 23-11). The typical hydraulic pump is usually a standard-type internal-external rotor-type pump (para

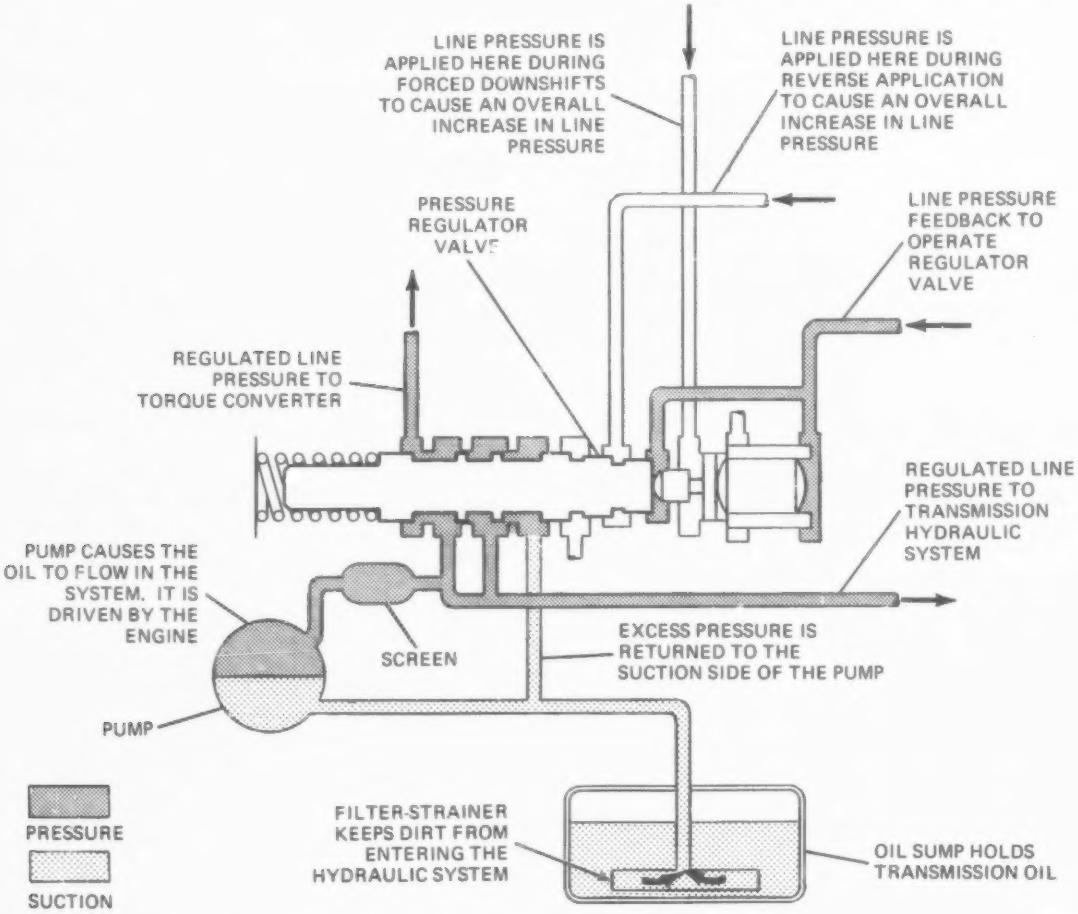

LINE PRESSURE IS APPLIED HERE DURING FORCED DOWNSHIFTS TO CAUSE AN OVERALL INCREASE IN LINE PRESSURE
LINE PRESSURE IS APPLIED HERE DURING REVERSE APPLICATION TO CAUSE AN OVERALL INCREASE IN LINE PRESSURE
PRESSURE REGULATOR VALVE
LINE PRESSURE FEEDBACK TO OPERATE REGULATOR VALVE
REGULATED LINE PRESSURE TO TORQUE CONVERTER
REGULATED LINE PRESSURE TO TRANSMISSION HYDRAULIC SYSTEM
PUMP CAUSES THE OIL TO FLOW IN THE SYSTEM. IT IS DRIVEN BY THE ENGINE
SCREEN
EXCESS PRESSURE IS RETURNED TO THE SUCTION SIDE OF THE PUMP
PUMP
PRESSURE
SUCTION
FILTER-STRAINER KEEPS DIRT FROM ENTERING THE HYDRAULIC SYSTEM
OIL SUMP HOLDS TRANSMISSION OIL

Figure 23-10. Typical Hydraulic Supply System. TA233707

451

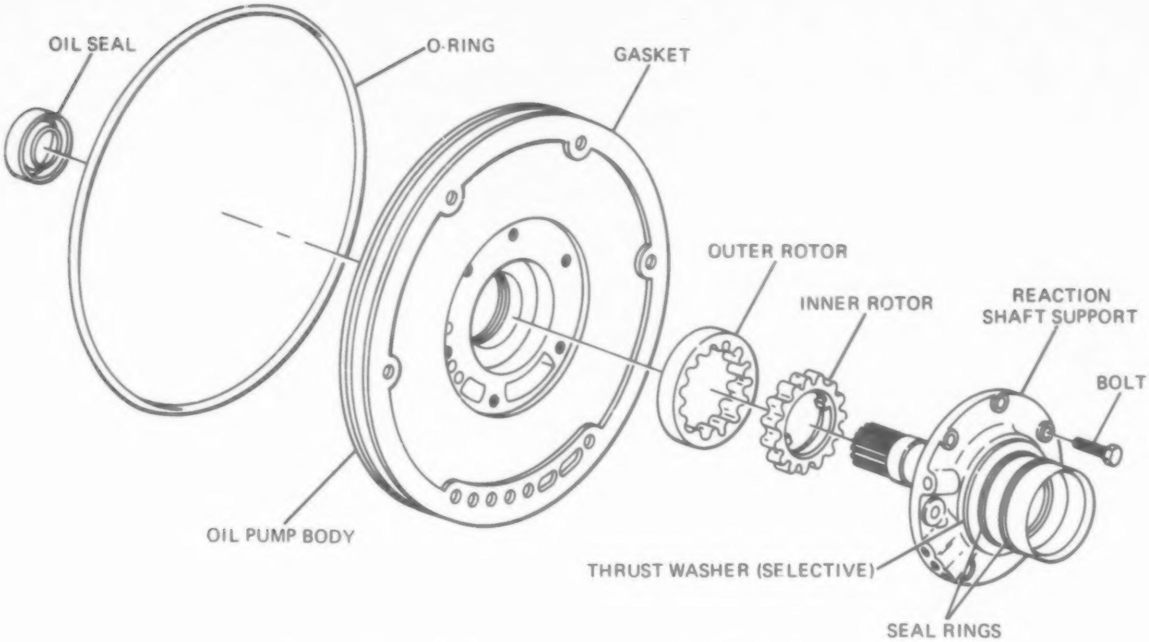


Figure 23-11. Typical Transmission Hydraulic Pump.

20-5) or an internal-external gear-type pump (para 20-7). It usually is located in the front of the transmission case and is keyed to the torque converter hub so that it is driven by the engine.

b. Oil Sump and Filter (Fig. 23-10). The oil sump usually is in the form of a sheet metal pan that attaches to the bottom of the transmission case. The pump draws oil from the sump through a strainer. The strainer usually is made of paper or metal.

c. Regulator Valve. The regulator valve controls the pressure of the hydraulic pump so that the hydraulic system of the transmission receives a constant working pressure. The pressure supply received by the hydraulic system is called line pressure. The basic regulator valve is shown in figure 23-10.

(1) Pump pressure is fed to the hydraulic system through the spool valve. The spool is held to the right by a calibrated spring. In this position, the spool closes the port that allows pump pressure to be fed back to the pump suction line.

(2) After the pump pressure leaves the spool valve, a portion of it is fed back to the end of the spool valve, opposite to the spring. This pump pressure signal attempts to move the spool against spring pressure.

(3) As pump pressure overcomes the spring pressure, the spool is pushed to the left, uncovering the pump suction feedback port. Pump pressure then is bled off through this port, causing a line pressure drop.

(4) The line pressure drop allows the spring to close the bleed port, which, in turn, allows pump pressure to build again. From then on the regulation of line pressure is a constant cycle between pump and spring pressure operating the spool valve.

The valve described above is a balance-type spool valve. Balance-type spool valves are very common in the transmission's hydraulic system.

d. Modulation of the Regulator Valve (Fig. 23-10). After the pump pressure passes through the regulator valve, it becomes regulated line pressure. In operation, however, automatic transmissions need more than one set line pressure. To accomplish this, additional signals are fed to the regulator to modulate the line pressure for specific purposes. The following considerations are the most common in the modulation of line pressure:

(1) Under normal conditions the regulator valve functions in an unmodulated mode as described in paragraph 23-12d. The normal line pressure is sufficient to operate the transmission and still maintain a smooth shifting quality.

(2) During periods of heavy acceleration, additional line pressure is required to hold the clutches and brake bands tight enough to transmit the increased engine torque. This is particularly important during the initial application of the elements during shift changes to minimize slippage during engagement, which would cause burning and premature wear of friction facings.

(3) Operation in reverse places additional torque requirements on the clutch or brake band that holds the element of the planetary gearset. For this reason, the line pressure is increased at least twofold during operation in reverse.

(4) Any condition that causes a drop below line pressure will cause the regulator valve to temporarily cut off the oil supply to the torque converter. A common occurrence of this condition is the shifting to reverse, which temporarily increases the requirements placed on the pump while the engine is idling and the pump is turning slowly.

Modulation of the line pressure is a fairly simple matter. Pressure signals are fed back into the regulator valve to assist the spring. The result is that the line pressure must increase to overcome the higher pressure before the suction feedback port is uncovered. The feedback signals come from the manual valve and the throttle modulation system.

23-13. Converter Feed Circuit (Fig. 23-12).

a. General. The torque converter supply, cooling, and lubrication tasks are all handled by the converter feed circuit of the hydraulic system. This intergration is a logical one for the following reasons:

(1) All phases of this circuit will function within approximately the same operating pressure range.

(2) The majority of the heat generated within the transmission originates in the torque converter. It is therefore logical that the oil, after it circulates through the torque converter, should pass directly to the cooler. This arrangement effectively isolates the transmission from this major heat source.

(3) One of the major reasons for lubrication within the transmission is to cool the localized areas where heat is generated between moving parts. For this reason, the lubrication of the transmission is handled by the oil after it is passed through the cooler.

b. Oil Supply. The supply of oil for the converter feed circuit passes through the regulator valve (para 23-12c). The regulator valve will cut off this oil supply if line pressure drops below an operating minimum. Under normal circumstances, however, the oil pressure cutoff will last no more than a few seconds and will not affect transmission operation. During periods of engine shutdown, the regulator valve also prevents the torque converter from draining back to the oil sump. This condition otherwise would require the pump to refill the converter at each engine restart, creating an unacceptable delay in operation.

c. Regulation of Circuit Oil Pressure. The regulator valve supplies the converter feed circuit at regulated line pressure. The converter feed circuit, however, requires a constant pressure that is independent of transmission operating modes and generally lower than line pressure. The converter control valve controls the pressure for the converter feed circuit. The converter control valve is a balance-type spool valve whose operating principles are much like that of the regulator valve (para 23-12c). When operating pressure is low, the calibrated spring pushes the spool to the left, opening the delivery port. As pressure reaches the desired level, the spool is forced to the right, blocking the delivery port. A metered orifice is usually provided between the torque converter and the cooler to control the volume of oil flow through the system.

d. Oil Flow Through the Torque Converter. Oil flow through the converter, in most cases, is as follows:

L53

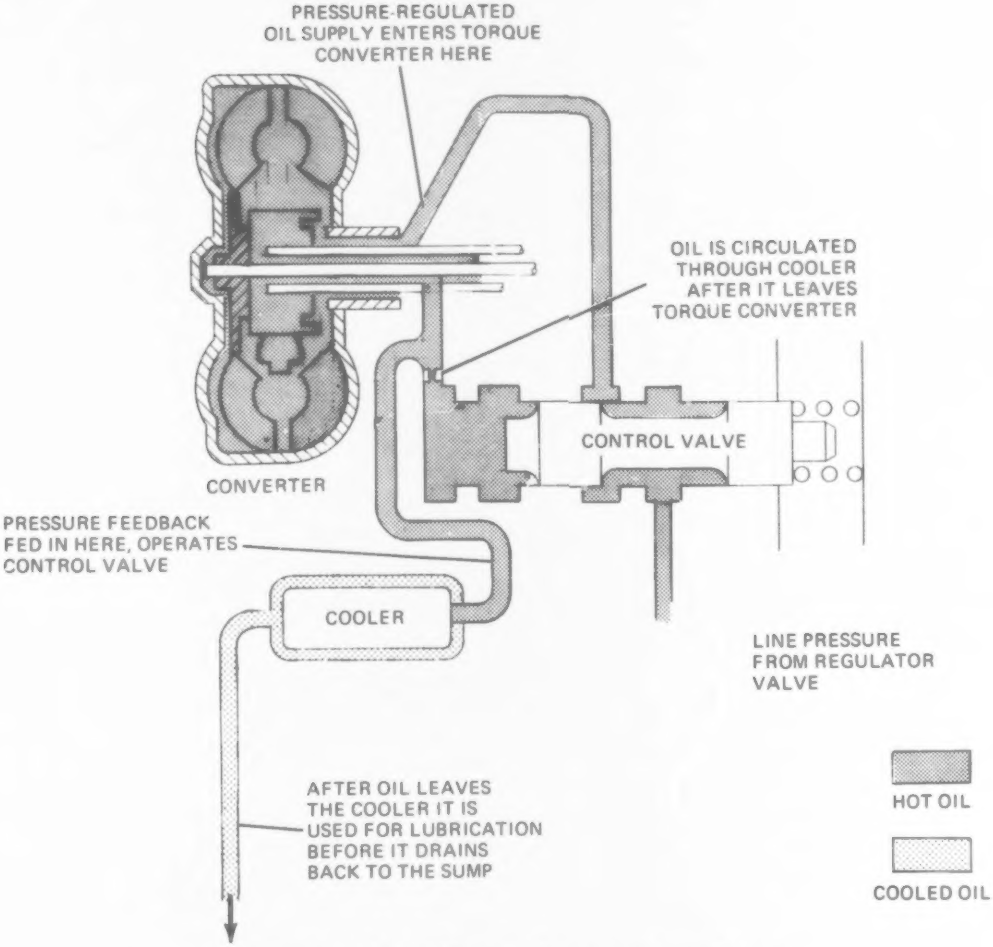

PRESSURE-REGULATED OIL SUPPLY ENTERS TORQUE CONVERTER HERE
OIL IS CIRCULATED THROUGH COOLER AFTER IT LEAVES TORQUE CONVERTER
CONTROL VALVE
CONVERTER
PRESSURE FEEDBACK FED IN HERE, OPERATES CONTROL VALVE
COOLER
LINE PRESSURE FROM REGULATOR VALVE
HOT OIL
COOLED OIL
AFTER OIL LEAVES THE COOLER IT IS USED FOR LUBRICATION BEFORE IT DRAINS BACK TO THE SUMP

Figure 23-12. Typical Torque Converter Feed Circuit.

(1) Oil passes from the converter control valve to the torque converter through internally drilled passages in the transmission case.

(2) The oil enters the torque converter through a clearance between the outside of the stator support and the inside of the converter hub.

(3) After the oil circulates within the converter, it exits through a clearance between the input shaft and the inside of the stator support shaft.

(4) The oil then passes through an internally drilled passage to the oil cooler outlet.

e. Cooler. The cooler is a heat exchanger that is located remotely from the transmission. The following are the most popular configurations:

(1) The most popular transmission cooler for use in light vehicles is integral with the engine radiator. The cooler is basically a pipe that extends for the entire length of the inside of the outlet tank of the radiator. As the oil passes through the cooler, a portion of its latent heat is transferred to the engine coolant. The oil then returns to the transmission. (It should be noted that there is no mixing or physical contact between the engine coolant and the transmission oil.)

(2) In heavy-duty use a separate oil-to-air type cooler is preferred. This is because in severe use, enough heat can be generated by the transmission to actually cause the engine to overheat if transmission heat is transferred directly to the engine coolant. The oil-to-air type heat exchanger is built much the same as an automotive radiator. It consists of a continuous

tubing arranged in rows. The rows of tubing pass through a series of fins. As the oil passes through the tubing, its latent heat is transferred to the air via conduction through the fins. This type of cooler usually is located in front of the engine radiator where it is subjected to airflow. This condition is important for its efficient operation.

f. Lubrication. After the oil is passed through the oil cooler, it is piped through internal passages in the transmission case to the rear section of the transmission where it provides lubrication for components such as the planetary gearsets and the output shaft bearings. The oil then drains back to the sump. (At this time, it should be noted that the oil sump also dissipates heat from the transmission oil and is considered to be a source of transmission cooling.)

23-14. Range Control System (Fig. 23-13).

a. General. The range control system provides automatic or operator-controlled shifting of the transmission. The shifting of the transmission is controlled by the following two indicators:

(1) *Manual Selection.* The position of the gearshift lever selected by the operator chooses the desired shifting program. The selections available to the operator of a typical two-speed unit are:

(a) Neutral (N). In neutral (N), the engine freewheels, providing no driving force to the vehicle.

(b) Drive (D). In drive (D), the transmission provides automatic shifting through the low- to high-gear ranges.

(c) Drive-Low (L). In drive-low (L), the transmission is locked in the low range and no automatic shifting occurs.

(d) Reverse (R). Reverse (R) reverses the direction of engine torque to drive wheels, and the vehicle is driven backwards.

(e) Park (P). Park (P) is the same as neutral except that the drive wheels are locked by a positive latching device within the transmission.

The three-speed transmission has all of the above selections plus drive second. This position allows for an automatic shift from first to second gear, but blocks an automatic shift from second to third gear.

(2) *Vehicle Speed Versus Engine Loading.* The shifting of the automatic transmission is controlled by two pressure signals that are indicators of speed and engine loading. These signals, as will be described later in this paragraph, work against each other to produce a shifting sequence.

The center of all shift control is the valve body. This unit, which can be thought of as a hydraulic computer, receives information from the indicators described above. Based on this information, the valve body switches line pressure to the proper planetary holding elements to produce the required gear range. As the information changes, the valve body changes its line pressure outputs accordingly. For the sake of simplicity, a two-speed transmission will be used to explain the operation of all of the typical components. A hypothetical, automatic transmission hydraulic system will be constructed in this paragraph . It must be stressed that this hypothetical system by no means contains all of the devices necessary in a real transmission. It is useful for the sake of learning, because it clearly illustrates how the decision and the action of shifting is initiated.

b. Manual Valve. The manual valve is the device that selects the desired shift program through the position of the gearshift lever. A manual valve is basically a multiport spool valve that switches line pressure to selected passages as it is moved through its operating positions. A hypothetical manual valve for a two-speed transmission is illustrated in figure 23-14 in all of its operating positions.

c. Governor. The governor modulates line pressure to produce a signal that is an indication of vehicle speed. This signal is used by the valve body to formulate gear-range selections for the transmission. The governor uses a spool valve that is operated by centrifugally operated weights. The weights are rotated by the output shaft of the transmission because it is solidly linked to the drive wheels and, therefore, consistently provides a true indication of vehicle speed. As the weights rotate they are acted on by centrifugal force which tends to pull them outward from the axis of rotation. The weights are pulled

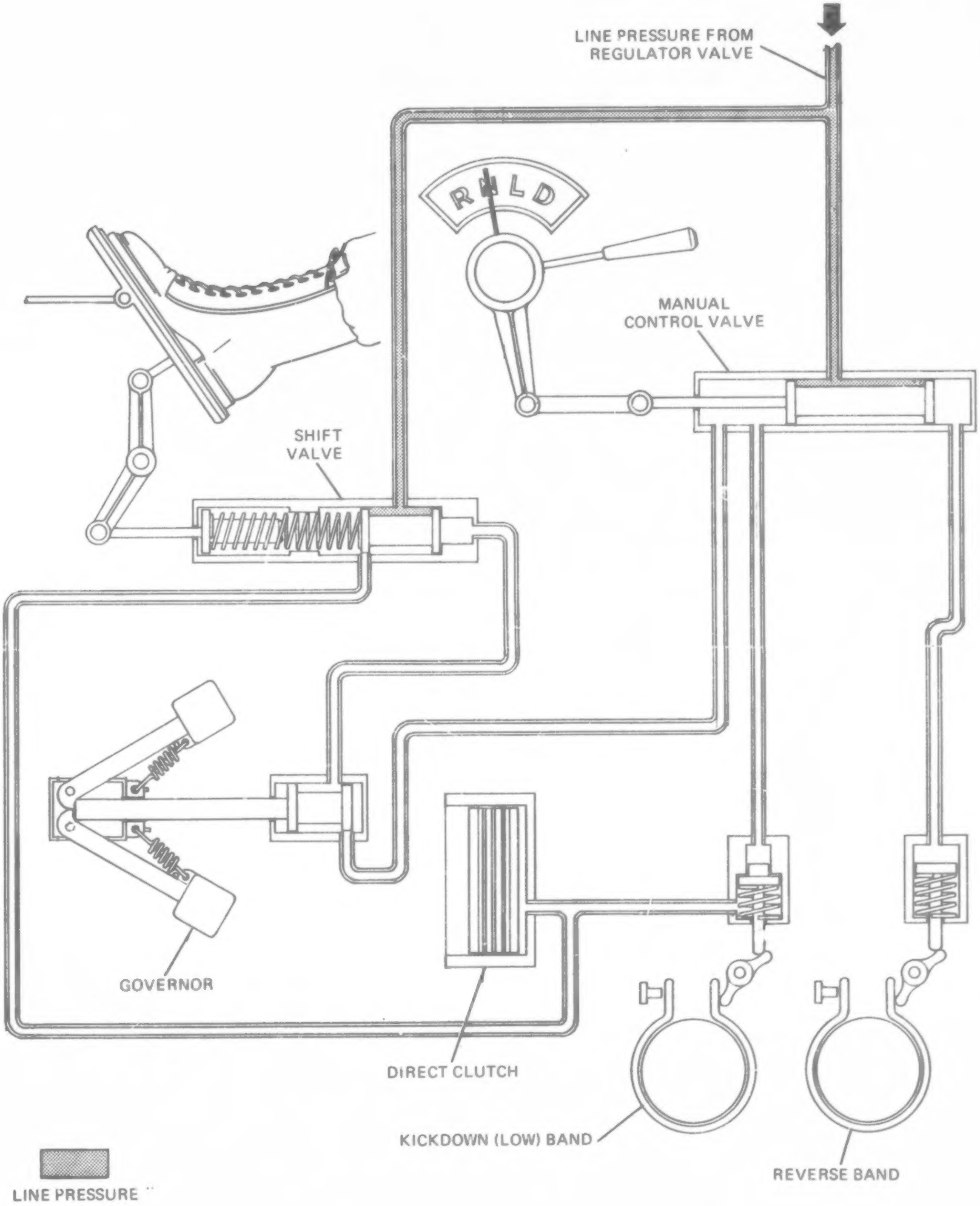

LINE PRESSURE FROM
REGULATOR VALVE
R N L D
MANUAL
CONTROL VALVE
SHIFT
VALVE
GOVERNOR
DIRECT CLUTCH
KICKDOWN (LOW) BAND
REVERSE BAND
LINE PRESSURE

Figure 23-13. Typical Range Control Circuit.

TA233710

456

CHAPTER 13

CHARGING SYSTEMS

Section I. PRINCIPLES OF OPERATION

13-1. General. The generator is a machine in which the principle of electromagnetic induction is used to convert mechanical energy into electrical energy. The generator restores the current used in cranking the engine to the battery. It also supplies, up to the limit of its capacity, current to carry the electrical load of the lights, ignition, radio, and horn. A generator and a motor are basically the same in construction and use the same electrical principles; however, their operation is opposite. In the generator, mechanical motion is converted into electrical energy. In the motor, electrical energy is converted into mechanical motion.

13-2. Simple Single-Loop Generator.

a. Induced Current. If a single loop of wire is rotated in the magnetic field between a north and a south pole, there will be an electrical pressure produced in the two sides of the loop. The voltage and current produced will relate to the direction of the magnetic field and the direction of rotation. If each end of the loop is connected to a metal segment of a commutator on which brushes rest (fig. 13-1), this electrical pressure will cause a current to flow through any external circuit that may be connected across the two brushes.

b. Commutation. If the loop is rotated through a complete revolution (fig. 13-1), sides 1 and 2 will cut magnetic lines of force in first one direction and then in the other. This will produce current in each side of the loop, first in one direction and then in the other. That is, in side 1, current will flow in one direction when it is passing the north pole and in the other direction when it is passing the south pole. However, because the commutator segments also rotate with the loop, the current always will leave the right-hand brush (4) and enter the left-hand brush (3). The directions of current produced in each side of the loop can be determined by use of the left-handed rule, described in paragraph 11-14.

13-3. Multiple-Loop Generator. The advantages of a multiple-loop generator are explained below.

a. More Current Induced. In the simple, single-loop generator (fig. 13-1), the current produced in each side of the loop reaches a maximum when the sides are cutting the lines of force in a perpendicular direction. This is the position in which the loop is shown. As the loop moves away from this position, it cuts fewer and fewer lines of force and less and less current is produced. By the time the loop has turned 90 degrees from the position shown, the sides are moving parallel to the lines of force and are cutting no lines, therefore no current is being produced. The current produced from the single loop is shown in graph form in figure 13-1. Many loops, or turns, of wire are required in the conductor in order for the generator to produce an appreciable amount and even flow of current. The rotating member that contains the wire loops and the commutator is called an armature. Figure 13-2 shows an armature in place in a generator. Note that many turns are used in the armature windings.

b. Smoother Current Flow. The windings are assembled in a soft iron core because iron is more permeable than other substances that could be used. The windings are connected to each other and to the commutator segments in such a way that the current impulses overlap and produce a smooth flow of current. This could be compared to the overlapping of power impulses in an 8- or 12-cylinder engine.

13-4. Generator Speed. In order for the generator to provide rated output, it must be operated at sufficient speed. Because military vehicles spend a large amount of time at engine idle, it is important to note that during these periods the generator may be required to supply full rated current on a large portion thereof. Therefore, the requirement for establishing the speed at which full rated output must be delivered is the controlling factor for optimizing the size of the generator. As a general rule, engines have a speed ratio between four and five to one from idle to maximum speed; that is, the typical engine idles at 650 rpm and has a maximum speed of 3,000 rpm. Typical

263

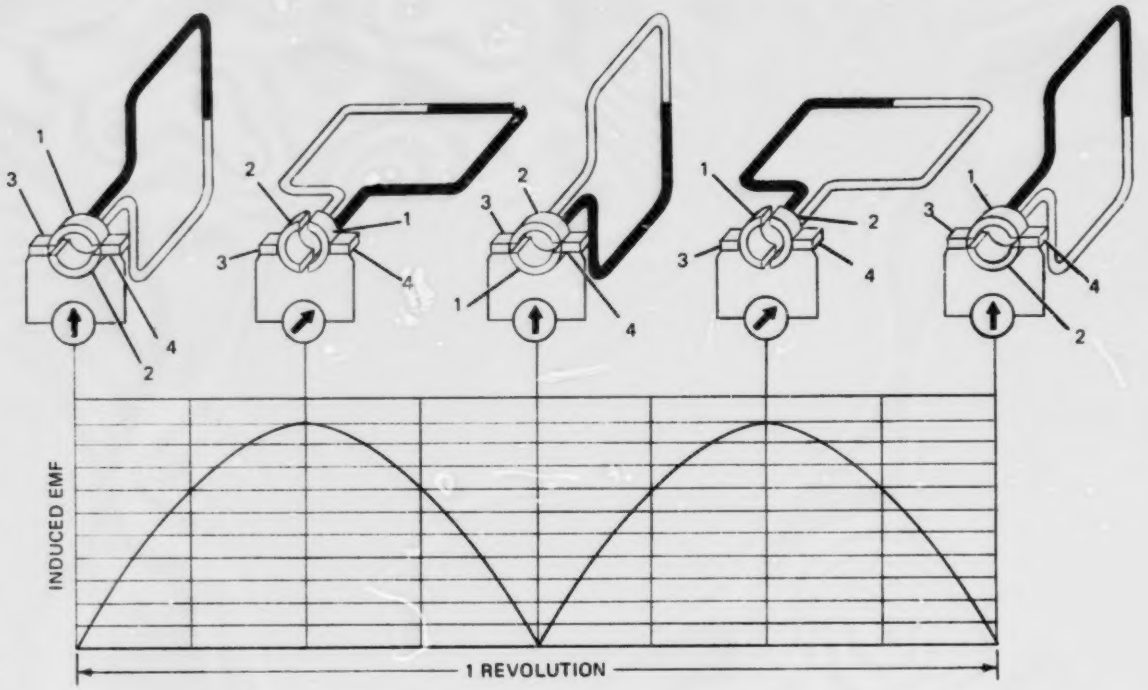

1
2
3
4
INDUCED EMF
1 REVOLUTION

Figure 13-1. Simple Single-Loop Generator.

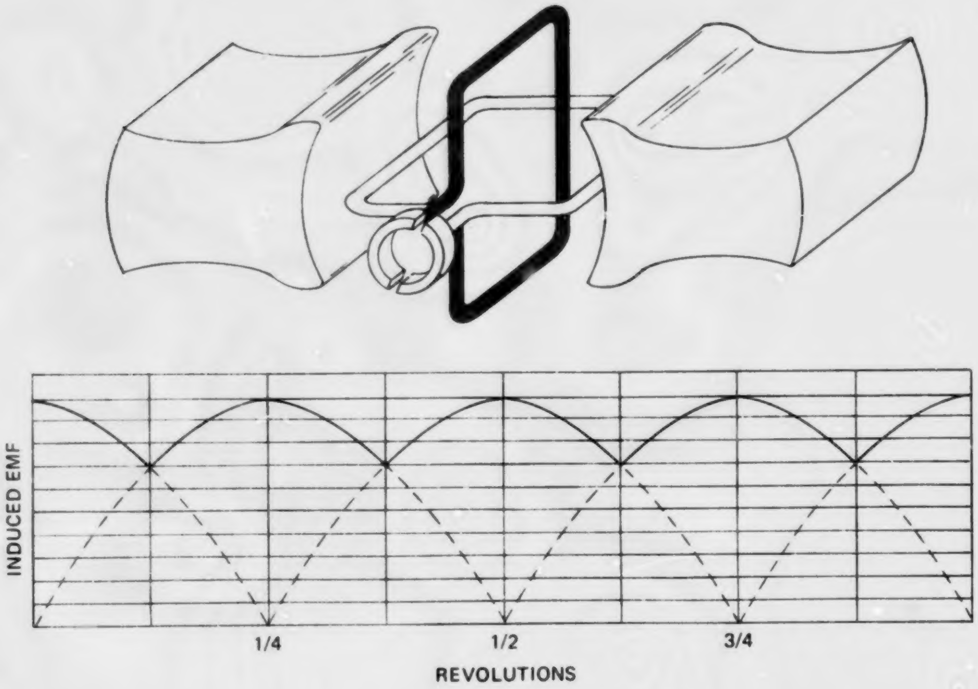

INDUCED EMF
1/4
1/2
3/4
REVOLUTIONS

Figure 13-2. Multiple-Loop Generator.

TA233542

264

generator speeds can be two to four times engine rpm.

13-5. Field Intensity. The magnetic lines of force that are created by the generator field are critical to the generator's output. The more lines of force that there are for the armature to cut, the more output the generator will produce. Generator field coils are designed to produce the most intense field that is possible. The key factors that affect field intensity are:

a. The number of wire turns in the coil.

b. The ratio of the coil's length to its width.

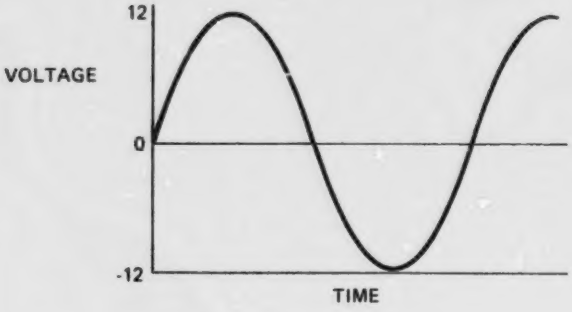
c. The type of material used in the core.

13-6. AC and DC Current Flow.

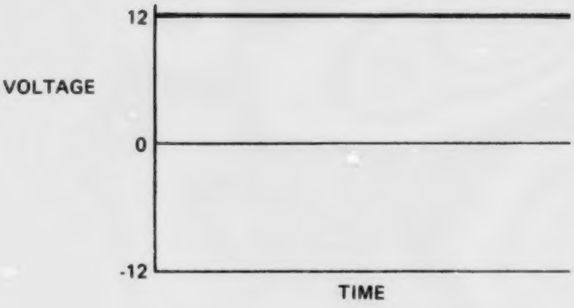
a. General. There are two basic forms of electrical current flow: Direct current (dc) and alternating current (ac).

b. Alternating Current. Alternating current forces electrons from one terminal to the other and then back again (the direction of current flow alternates). A graph of the voltage versus time for alternating current is shown in figure 13-3. It can be seen that the value of the voltage rises in the positive direction, reaches a peak, falls in the negative direction, reaches a negative peak, and then rises to zero. This is a constantly repeating cycle. Generators normally produce alternating current.

c. Direct Current. Direct current flow forces electrons from the negative terminal to the positive terminal (current flow is always in one direction or direct). Direct current voltage versus time is shown in figure 13-3.



ALTERNATING CURRENT



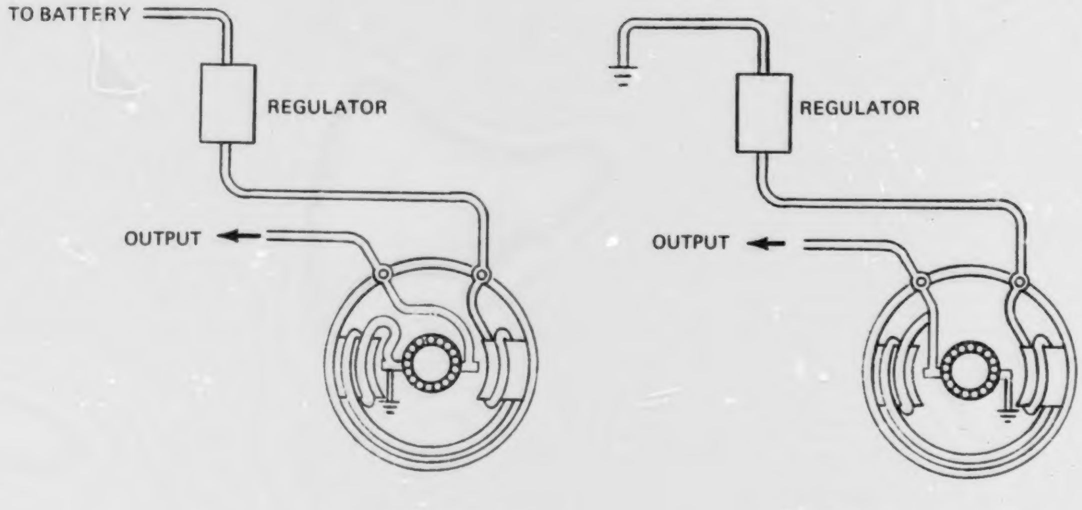
DIRECT CURRENT

Figure 13-3. AC and DC Flow.

d. Compatibility. An automotive electrical system, due to the need for a storage battery that produces dc flow, must also have a dc flow, because ac and dc flow are incompatible in the same circuit. To correct this problem, the generator output therefore must be changed to dc through a process called rectification. By its design, a dc generator is self-rectifying, but an ac generator must have its output rectified electronically. The processes of rectification are respectively covered in their related sections.

Section II. DC GENERATOR PRINCIPLES

13-7. Field Winding Configurations (Fig. 13-4). The purpose of the field windings is to create the lines of force electromagnetically that induce a current flow in the armature. The field winding usually is connected in parallel with the armature winding (that is, across the brushes). This is called shunt-field winding. The shunt-field winding usually is connected only at one end to the brushes. The other end of the field winding then is made to pass through a voltage regulation circuit (para 13-13). In this manner, the output of the generator is controlled. Depending on the



"A" TYPE FIELD CIRCUIT

"B" TYPE FIELD CIRCUIT

Figure 13-4. Field Winding Configurations.

regulation circuitry used, the field windings may be connected in one of two ways.

a. A-Type Field Circuit. The A-type field circuit shunts one end of the field winding to the negative generator brush and controls output through the regulation circuitry to the positive (battery) connection.

b. B-Type Field Circuit. The B-type field circuit shunts one end of the field winding to the positive generator brush and controls output through the regulation circuitry to the negative (ground) connection.

13-8. Shunt-Wound Generator (Fig. 13-5).

a. General. Most motor vehicle generators are shunt wound, with an outside means of regulating the voltage output. Approximately 8 to 12 percent of the total current generated by the armature is shunted (sent) through the field coils for producing the magnetic field.

b. Components. The generator essentially consists of an armature, a field frame, field coils, and a commutator with brushes to establish electrical contact with the rotating element. The magnetic field of the generator usually is produced by electromagnets or poles magnetized by current flowing through the field coils. Soft iron pole pieces (or pole shoes) are contained in the field frame that forms the magnetic circuit between the poles. Although machines may be designed to have any even number of poles, two- and four-pole frames are the most common.

c. Field Frames. In the two-pole type frame, the magnetic circuit flows directly across the armature, while in the four-pole type each magnetic circuit flows through only a part of the armature core. Therefore, the armature must be constructed in accordance with the number of field poles because current is generated when the coil, winding on the armature, moves across each magnetic circuit.

d. Brushes and Commutator. The current is collected from the armature coils by the brushes (usually made of carbon) that make rubbing contact with a commutator. The commutator consists of a series of insulated copper segments mounted on one end of the armature, each segment connecting to one or more armature coils. The armature coils are connected to the external circuit (battery, lights, or ignition) through the commutator and brushes. Current induced in the armature coils thus is able to flow to the external circuit.

e. Principle of Operation. In figure 13-6, assume that the magnetic field flows from the north pole piece (N) to the south pole piece (S), as indicated by the arrows. When the armature is

TA233544

266

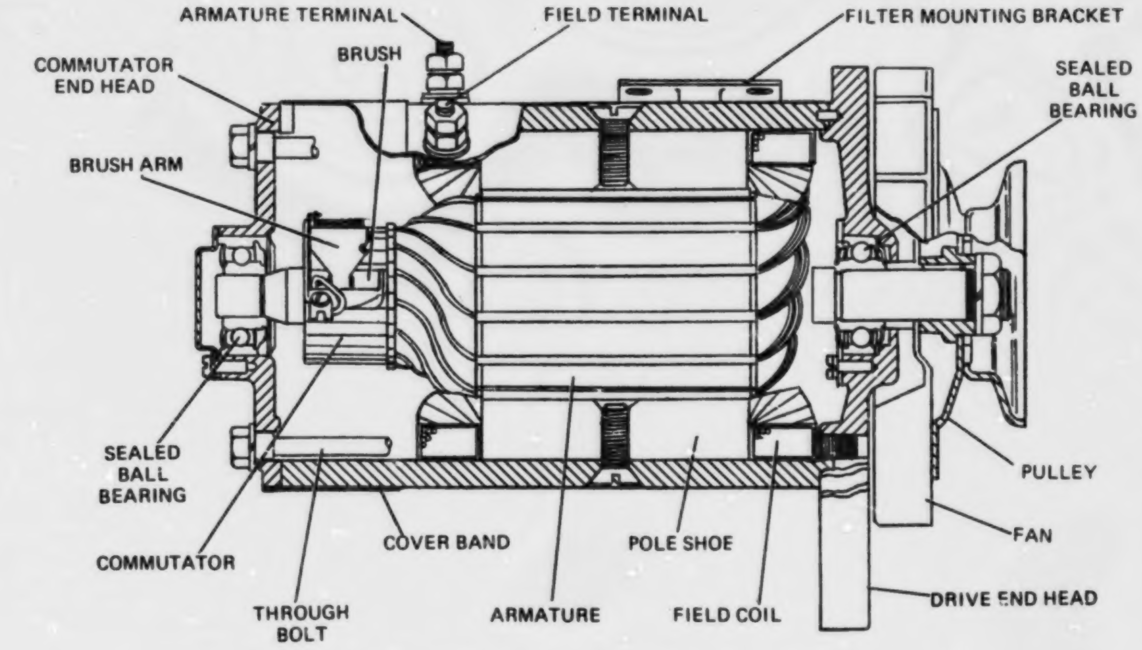

ARMATURE TERMINAL
FIELD TERMINAL
FILTER MOUNTING BRACKET
COMMUTATOR END HEAD
BRUSH
SEALED BALL BEARING
BRUSH ARM
SEALED BALL BEARING
PULLEY
FAN
COMMUTATOR
COVER BAND
POLE SHOE
DRIVE END HEAD
THROUGH BOLT
ARMATURE
FIELD COIL

Figure 13-5. Shunt-Wound Generator.

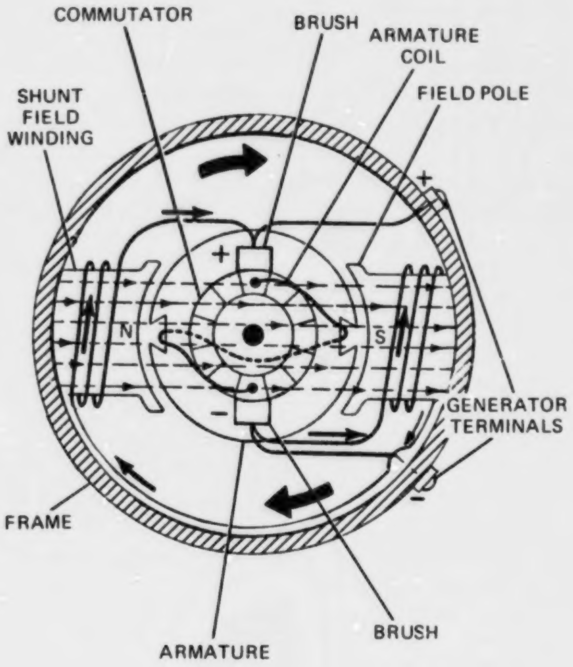

COMMUTATOR
BRUSH
ARMATURE COIL
SHUNT FIELD WINDING
FIELD POLE
+
N
S
−
GENERATOR TERMINALS
FRAME
ARMATURE
BRUSH

Figure 13-6. Shunt-Wound Generator Operation.

rotated, the armature coils will cut the weak magnetic field (residual magnetism) retained by the poles and set up a slight voltage, usually 1 to 1 1/2 volts, across the brushes. In this particular case, the upper brush will be positive (+) and the lower brush will be negative (-). This voltage is sufficient to cause a small current to flow from the negative brush through the field winding around the pole pieces to the positive brush. If the magnetic effect of this field current is of the same polarity as the remaining magnetism, the pole strength will be increased. This, in turn, will increase the magnetic field through the armature. Because the armature coils then will be cutting more magnetic lines of force per revolution, the voltage across the brushes will be increased. An increase in brush voltage increases the field strength which, in turn, increases the armature output. The armature voltage helps the field and the field helps the armature voltage until the generator reaches its normal operating voltage at the specific running speed. This process is called building up the generator voltage.

f. Residual Magnetism. The importance of the magnetism retained by the poles should be noted in the description of generator operation because it serves as a foundation for building up the generator voltage. Residual magnetism is

TA233545

267

BEST COPY AVAILABLE

the magnetism remaining in the pole pieces after the field-magnetizing current has stopped. If there is no residual magnetism in the pole pieces, there will be no initial output of the generator, and it will not build up voltage to push current. If the pole pieces lose residual magnetism through long storage, or by being newly rebuilt, subjected to extreme heat or cold, dropped, vibrated, or struck by a sharp blow, it can be restored by passing direct current through the field winding in the proper direction. If current is passed through the field windings in the reverse direction, the generator will be polarized in reverse. This reverse polarity will cause the generator to discharge the batteries instead of charging them, and also could cause damage to some of the vehicle accessories. Several conditions are necessary for the generator to build up a voltage. Two of the most important requirements are that the pole pieces have residual magnetism as a foundation on which to build, and that the current in each field coil be in a direction around the pole that it will produce magnetism to assist, and not oppose, the residual magnetism. If the field current opposes it, the voltage built up will not be higher than that produced by the residual magnetism.

g. Construction. The armature core is made of sheets of iron insulated from each other so that the magnetic field will not induce eddy currents in the core. Eddy currents are currents that are induced within the core by the constant variation in the lines of force. Making the armature core in one piece would allow eddy currents to become large enough to create a countervoltage, which would result in a large portion of the generator's output to be converted to heat. The armature core is wound with coils of copper wire and mounted on a shaft with a commutator on one end. Field coils are made of many coils of fine wire arranged for shunt connection. The field frame, usually two or four poles with brushes, brush holders, and end housings with bearings, completes the essential parts of the generator.

h. Generator Drives (Fig. 13-7). The method of mounting and driving the generator depends to a large extent on the construction and design of the engine. It usually is mounted on the side of the engine and driven by belts or gears at one to one and one-half times the crankshaft speed.

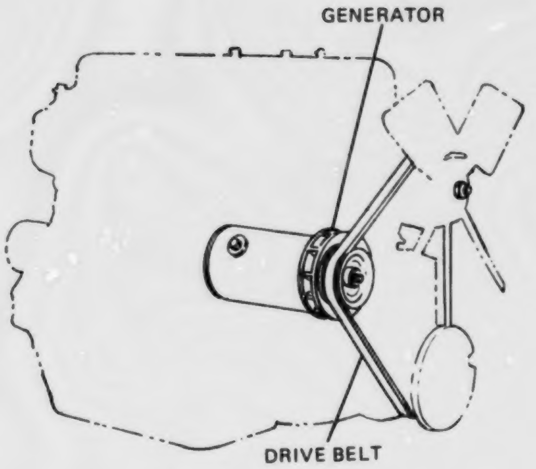


Figure 13-7. Generator Drive Systems.

The present trend is to have the water pump and generator driven by a V-type drivebelt from the pulley on the forward end of the crankshaft. Pivoting the generator on the generator mounting studs allows adjustment of the belt tension. A rotary fan usually is contained on the generator pulley to draw cooling air through the generator.

13-9. Waterproofed Generator Systems. The generators, as well as other electrical components, are made watertight on military vehicles that ford bodies of water. This is done by completely sealing the generator so that water cannot enter. In addition, stainless steel bearings are used to prevent corrosion. The commutator-end bearing is packed with heat-resistant grease on assembly, while the drive-end bearing is lubricated by a pickup gear rotating in an oil reservoir. Neither bearing requires attention or lubrication between generator overhauls. Other types of sealed bearings also may be used. The generator leads are carried in a waterproof conduit that is connected by plug-ins to the generator terminals. The conduit is attached to the generator terminal assembly by a waterproof coupling.

13-10. Circuit Breaker or Cutout Relay (Fig. 13-8).

a. Purpose. The circuit breaker is simply an

TA233546

268

BEST COPY AVAILABLE

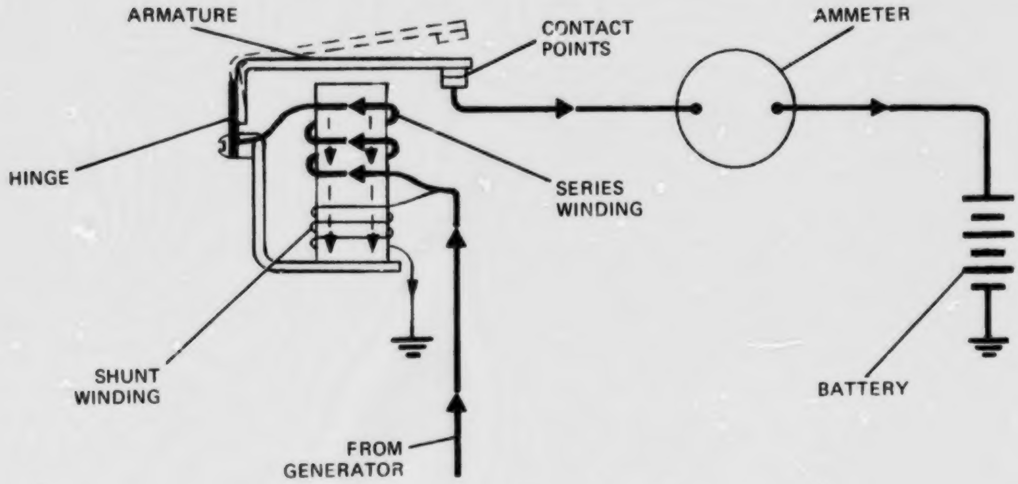


Figure 13-8. Cutout Relay.

automatic electromagnetic switch connected in the battery charging circuit between the generator and the storage battery of the electrical system. Its function is to connect the generator automatically to the battery when the voltage of the generator is sufficient to charge the battery. It also must disconnect the generator and battery when the generator is not running or when its voltage falls below that of the battery, to prevent the battery from discharging through the generator windings. In these respects, the action of the circuit breaker is very similar to that of a check valve between a pump and a reservoir.

b. Construction. The circuit breaker consists of two windings: a shunt winding and a series winding. These are assembled on a single core, above which is placed an armature. The shunt winding consists of many turns of fine wire, and is connected across the generator. The series winding consists of a few turns of heavy wire designed to carry full generator output, and is connected to the charging circuit. The armature operates a moving contact point that is positioned above a stationary matching point. Common practice is to place the cutout relay inside the voltage regulator.

c. Operation. When the generator is not operating, the armature is held away from the winding core by spring tension, and the points are separated. As soon as the generator begins to operate at a speed sufficient to produce enough voltage to charge the battery, this voltage, which is impressed on the relay windings, creates enough magnetism to overcome the armature spring tension and close the points. As long as the generator charges the battery, the points are held closed. When the generator slows or stops, so that current flows from the battery to the generator, the points open. They open because the series-winding magnetic field reverses as the current in it reverses, so that the two windings no longer help each other. The magnetic fields buck, causing a reduction of the total magnetic field to a point where it can no longer hold the armature down and the points closed. The spring tension pulls the armature up and opens the points. The air gap between the armature and the iron core of the relay has little or no effect upon the voltage at which the circuit breaker opens, because the spring tension governs this almost entirely. On the other hand, the voltage at which the circuit breaker closes is governed by both the air gap and the spring tension.

13-11. Regulation of Generator Output. The fields of the generator depend upon the current from the armature of the generator for magnetization. Because the current developed by the generator increases in direct proportion to its speed, the fields become stronger as the speed increases and correspondingly, more current is generated by the armature. The extreme variations in speed of the automotive

TA233547

269

engine make it necessary to regulate the output of the generator to prevent excessive current or voltage overload. On the average motor vehicle, a charging current in excess of 12 to 15 amperes may be harmful to a fully charged battery if continued too long. With the increased use of electrical accessories, generators have been increased in output until they are capable of producing far more than 15 amperes. Some heavy-duty generators, for example, may produce as much as 150 amperes.

13-12. Reverse-Series Field Generator (Fig. 13-9). The reverse-series field generator is self-regulating.

a. Operation. Because the output of the generator depends on the number of conductors in the armature, their speed of rotation, and the strength of the magnetic field in which they rotate, varying the strength of this field is the only convenient method of regulation. One of the simplest methods, used on special applications, is the use of a reverse-series field for differential action. A shunt field is connected across the brushes to produce the magnetizing action.

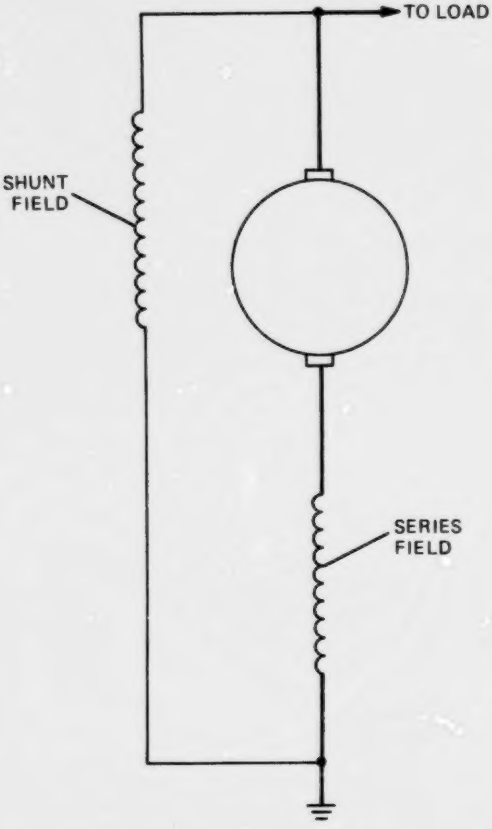


Figure 13-9. Reverse-Series Field.

Charging current going through the reverse-series field, however, has a demagnetizing action so that, as the current increases, it tends to restrict the rise of current above a reasonable value.

b. Disadvantages. This type of differentially wound generator has disadvantages that limit its use on motor vehicles without some additional external regulator. If a break should occur in the charging circuit (except during normal circuit breaker operation), destroying generator regulation by the series field, the voltage will become excessive. This usually results in damage to the field and armature winding and to the voltage winding of the circuit breaker. Therefore, such generators usually have some form of external voltage regulation.

13-13. Vibrating Point Regulator.

a. Current Regulation.

(1) The vibrating regulator (fig. 13-10) can be used to regulate the current or the voltage, depending on how the regulator coil is connected. A circuit diagram of a typical vibrating regulator used for limiting the current from the generator is shown in figure 13-11. The regulator consists of a soft iron core, a heavy winding or current coil around the core, a set of regulator contact points normally held closed by spring tension, and a resistance unit connected across the two regulator contact points.

(2) As the generator output increases, the current regulator prevents the current output of the generator from exceeding its rated maximum. It does this by cutting a resistance intermittently in and out of the shunt-field circuit as the regulator contact points open and close, due to the varying magnetic pull of the core. The resistance is connected in the shunt-field circuit, but normally is short circuited by the regulator contacts when they are closed. One of these is mounted on a soft iron contact armature, to which the spring for holding the points in contact is attached. The

TA233548

220

BEST COPY AVAILABLE

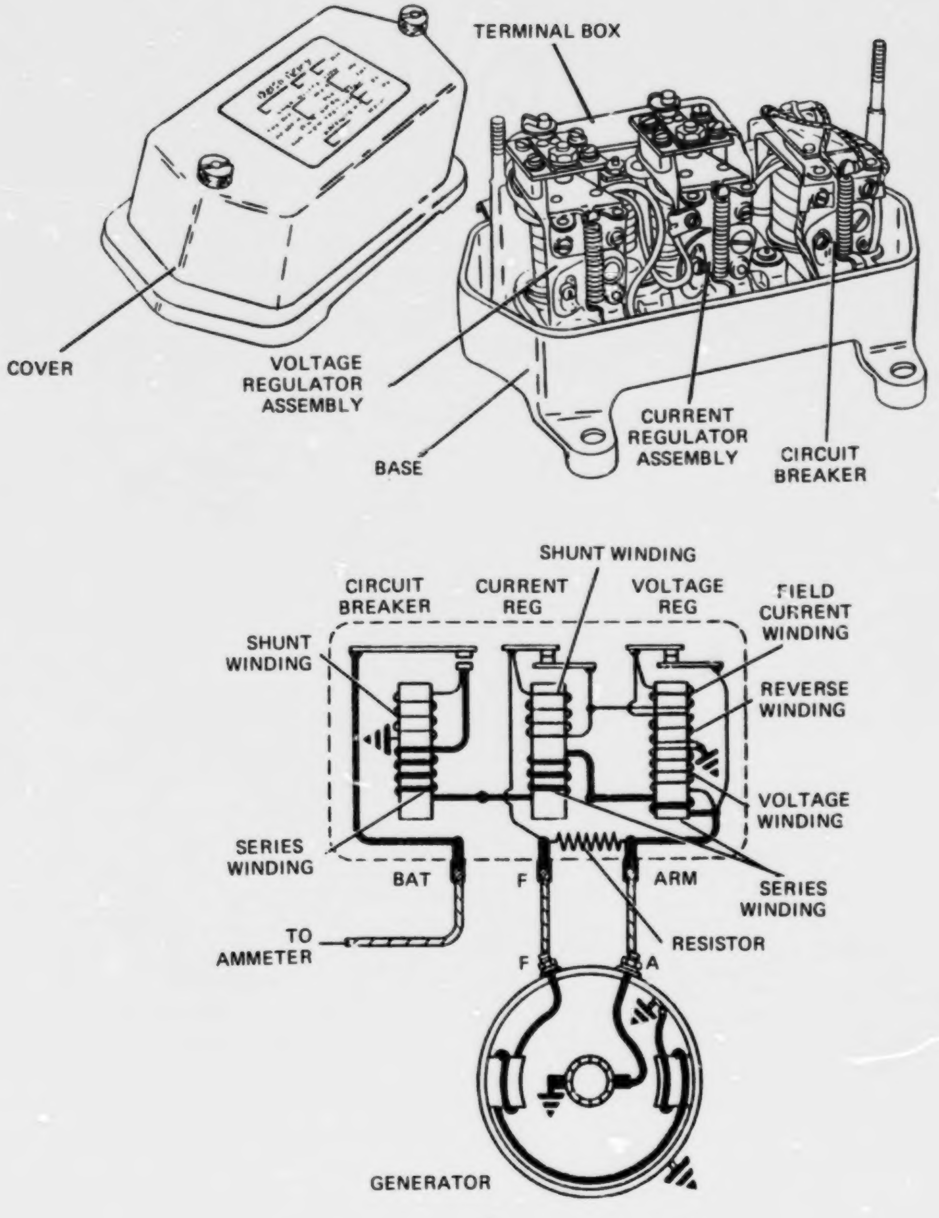

TERMINAL BOX
COVER
VOLTAGE REGULATOR ASSEMBLY
BASE
CURRENT REGULATOR ASSEMBLY
CIRCUIT BREAKER
SHUNT WINDING
CIRCUIT BREAKER
CURRENT REG
VOLTAGE REG
FIELD CURRENT WINDING
SHUNT WINDING
REVERSE WINDING
VOLTAGE WINDING
SERIES WINDING
BAT
F
ARM
SERIES WINDING
TO AMMETER
RESISTOR
F
A
GENERATOR

Figure 13-10. Vibrating Point Voltage Regulator.

generator, when driven by the engine, builds up as a simple shunt-wound generator. When the speed and voltage of the generator are increased sufficiently to close the circuit breaker, the generator will begin to charge the battery, the charging current flowing through the regulator winding. This current flowing through the regulator winding will magnetize the core. It, in turn, exerts a magnetic pull on the regulator contact armature, which tends to separate the contacts. When the battery-charging current reaches the value for which the regulator is adjusted, the core is sufficiently magnetized to attract the armature, overcoming the pull of the regulator spring. This separates the contact points and inserts the resistance unit in series with the shunt-field winding and weakens the field strength. This causes a drop in voltage generated in the

TA233549

271

armature, which then decreases the charging current. When the current decreases to a predetermined amount, the current coil does not magnetize the core sufficiently to overcome the pull of the spring, which then closes the contacts. With the contacts closed, the resistance unit is once more short circuited and the full field strength is restored, causing the charging current to increase again. The regulator will continue to repeat this cycle. Under operating conditions, the armature vibrates rapidly enough to keep the generator output constant. As a result, the generator will never produce more than the predetermined rate (for example, 40 amperes), no matter how high the speed of the car. This will be true regardless of the connected electrical load.

(3) This method of generator regulation is termed current regulation, because the current output of the generator is used for regulation. It is very important, therefore, that no breaks occur in the charging circuit after the generator reaches a voltage that will operate the circuit breaker. If a break does occur, no current will flow through the current coil to operate the vibrating points and, due to lack of regulation, the generator will build up an excessive voltage at high speeds. A voltage regulator is used to prevent excessive voltage.

(4) The charging rate of the generator can be adjusted easily in all electrical systems controlled by a vibrating regulator. To increase the maximum charging rate, the spring tension on the vibrating armature should be increased slightly. To decrease the maximum charging rate, the spring tension should be decreased. Care must be taken that the generator output does not exceed the value for which it was designed.

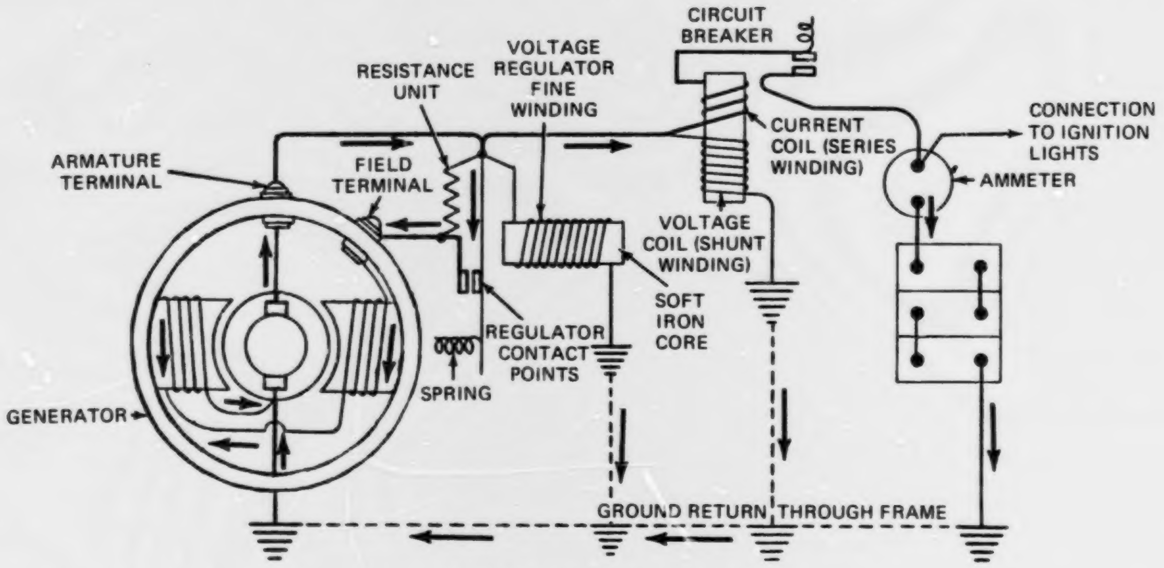
b. Voltage Regulation.

(1) A circuit diagram of a typical vibrating voltage regulator is shown in figure 13-11. Although the construction of this relay does not differ materially from that of the current regulator, the principle of operation is somewhat different. With this regulator, the voltage output of the generator is used for automatic regulation. By comparing both circuits, it will be seen that the principal difference in the two regulators is in the winding of the controlling coil and its connections. In the voltage regulator, the charging current does not flow through the regulator winding. The winding on the core consists of a voltage coil of fine wire. The two ends of the voltage coil are connected across the generator brushes and in parallel with the battery instead of in series with it. The iron core, regulator points, and resistance unit, however, are practically the same; the only important exception is that the voltage regulator resistance is considerably higher than that used with the current regulator.

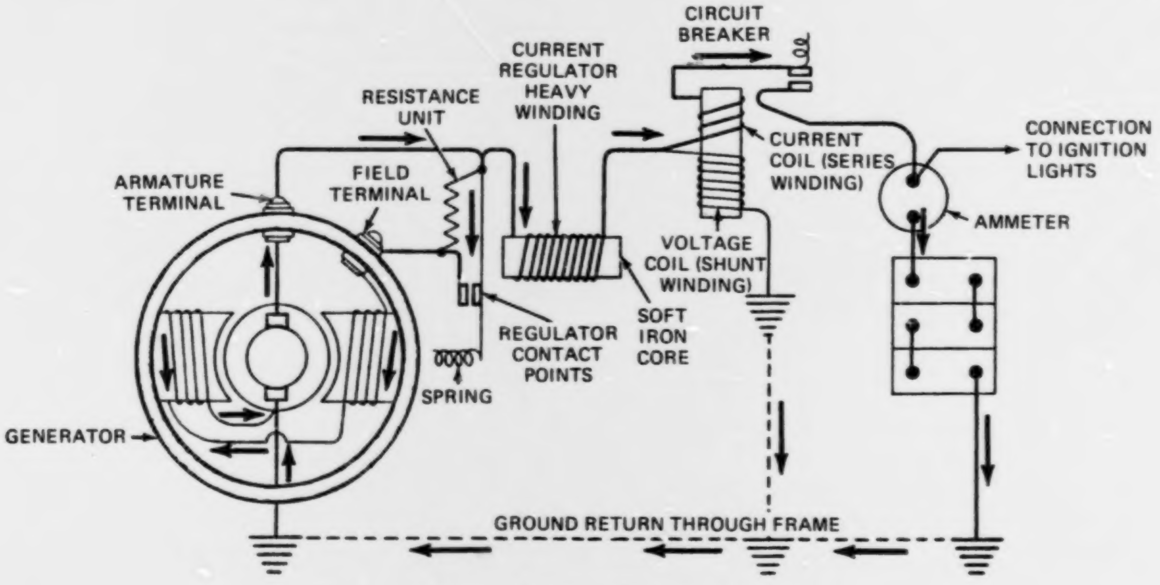
(2) The current flowing in the regulator coil and resultant magnetic pull of the core on the contact armature depend on the voltage developed by the generator. For an example of regulator operation, assume that the regulator is adjusted to operate at 12.8 volts. With increasing generator speed, the voltage tends to rise above 12.8 volts. However, if this value is exceeded by a small amount, the increased magnetic pull of the core on the contact armature due to the current flowing in the voltage coil will overcome the spring tension and pull the armature toward the core. This action will open the contacts and insert a resistance in the generator field circuit. This added resistance decreases the current in the field winding, and the voltage developed by the armature drops below 12.8 volts.

(3) When the voltage drops, the pull of the spring on the regulator armature overcomes the magnetic pull of the core and closes the contacts. This short-circuits the resistance unit and allows the field current to increase. The cycle of operation is repeated rapidly, preventing the generator voltage from rising above that for which the regulator is set. The regulator on most late-type military equipment will prevent the generator from building up an excessive voltage if a break occurs in the charging circuit. But this is not true on standard passenger cars and light-duty equipment. In these, if a break occurs in the voltage regulator circuit, regulation of the generator may be lost and at high speeds an excessive charging rate will result.

(4) It is obvious that increasing the tension of the regulator spring will increase the output voltage of the generator. Under no circumstances should the regulator spring tension be increased in an attempt to have the generator charge at a higher rate at lower speeds. The generator cannot begin to charge until the circuit breaker closes. The closing of the circuit breaker


CIRCUIT BREAKER
VOLTAGE REGULATOR FINE WINDING
RESISTANCE UNIT
CURRENT COIL (SERIES WINDING)
CONNECTION TO IGNITION LIGHTS
ARMATURE TERMINAL
FIELD TERMINAL
AMMETER
VOLTAGE COIL (SHUNT WINDING)
SOFT IRON CORE
REGULATOR CONTACT POINTS
SPRING
GENERATOR
GROUND RETURN THROUGH FRAME

VOLTAGE REGULATOR CIRCUIT


CIRCUIT BREAKER
CURRENT REGULATOR HEAVY WINDING
RESISTANCE UNIT
CURRENT COIL (SERIES WINDING)
CONNECTION TO IGNITION LIGHTS
ARMATURE TERMINAL
FIELD TERMINAL
AMMETER
VOLTAGE COIL (SHUNT WINDING)
SOFT IRON CORE
REGULATOR CONTACT POINTS
SPRING
GENERATOR
GROUND RETURN THROUGH FRAME

CURRENT REGULATOR CIRCUIT

Figure 13-11. Vibrating Point Regulator Circuit.

TA233550

is independent of the action of the regulator. Increasing the tension of the regulator springs so that the generator will develop an excessive voltage will send excessive current to the battery, overcharging it. It also will cause the generator to overheat, possibly burning it out.

c. Charging Rate.

(1) *Current Regulator.* With the vibrating current regulator, the maximum possible charging current remains constant for any one setting of the regulator, regardless of the condition of the battery. To vary this maximum generator output, the spring tension of the regulator must be adjusted. The setting must never exceed the rated maximum of the generator.

(2) *Voltage Regulator.*

(a) The main advantage of the voltage regulator is that the output of the generator is controlled to a great extent by the amount of charge in the battery. When the generator reaches a speed at which it develops the regulated voltage, there will be no further increase in voltage with increasing speed. The voltage will be maintained constant at all loads and at all higher speeds.

(b) During the time the generator is connected to the battery, the difference in voltage between the two is the voltage available for sending current into the battery. In a discharged battery, the difference in voltage between the generator and the battery will be relatively great, so that a comparatively high charging current will pass from the generator to the battery. As the charge continues, the voltage of the battery increases, so that the difference in voltage between the generator and the battery is diminishing continually. With a fully charged battery, the voltage is equal nearly to that of the generator so that the difference between the two is very slight. As this slight difference in voltage is all that is available for sending current into the battery, the charging current will be small. The charging current, therefore, is variable and depends upon the charge in the battery. In practice, the charging current with the constant voltage regulator varies from a maximum of 25 to 35 amperes for a discharged battery to a minimum of 4 to 6 amperes for a fully charged battery.

13-14. Carbon-Pile Regulator (Fig. 13-12).

a. General. In the vibrating-contact type regulator, a set of contacts open and close to insert and remove a resistance in and from the generator field circuit. This, in effect, inserts a variable resistance into the field circuit that controls the generator. When only a small output is required, the voltage regulator maintains the resistance in the field circuit most of the time. When output requirements increase, the resistance is in the field a smaller part of the time. This same variable-resistance effect can be achieved by a carbon-pile regulator.

b. Construction. The carbon-pile regulator consists essentially of a stack of carbon disks held together by spring pressure. The spring pressure is applied by an armature. The resistance through the carbon pile is relatively small with full spring pressure applied. But with less pressure, the resistance increases. The carbon pile is connected to the generator field circuit so that its resistance is in series with the field. With full pressure applied, there is no regulation and generator output can increase to a high value. To

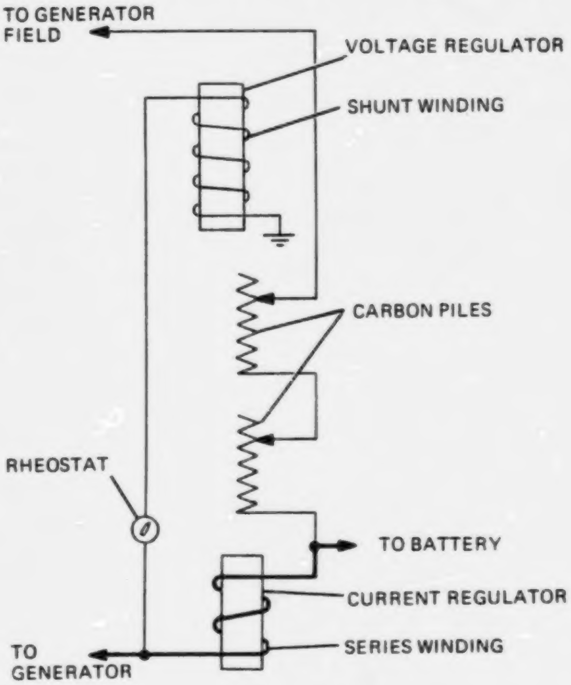


Figure 13-12. Carbon-Pile Regulator and Circuit.

TA233551

limit current output to a safe value, or to provide voltage regulation, the armature pressure can be adjusted to vary the resistance.

c. Current Regulation. To limit current, or to provide current regulation, the carbon-pile regulator has a heavy winding through which all current from the generator must pass. This winding produces a magnetic pull as current passes through it, which opposes the armature spring pressure. When the output reaches the value for which the generator is rated, the magnetic pull overcomes the spring pressure sufficiently to reduce the pressure on the carbon disks and thereby increase the resistance of the pile. This increased resistance, which is in the generator field circuit, prevents any further increase of output.

d. Voltage Regulation. A winding is incorporated in the carbon-pile voltage regulator to regulate voltage. This shunt winding is connected across the generator so that generator voltage is forced on it. When this voltage reaches the value for which the regulator is set, the winding produces enough magnetic pull on the armature to reduce the armature spring pressure. This causes the resistance of the voltage-regulator carbon pile to increase. The increased resistance, which is in the generator field circuit, prevents any further generator voltage increase and thereby reduces generator output.

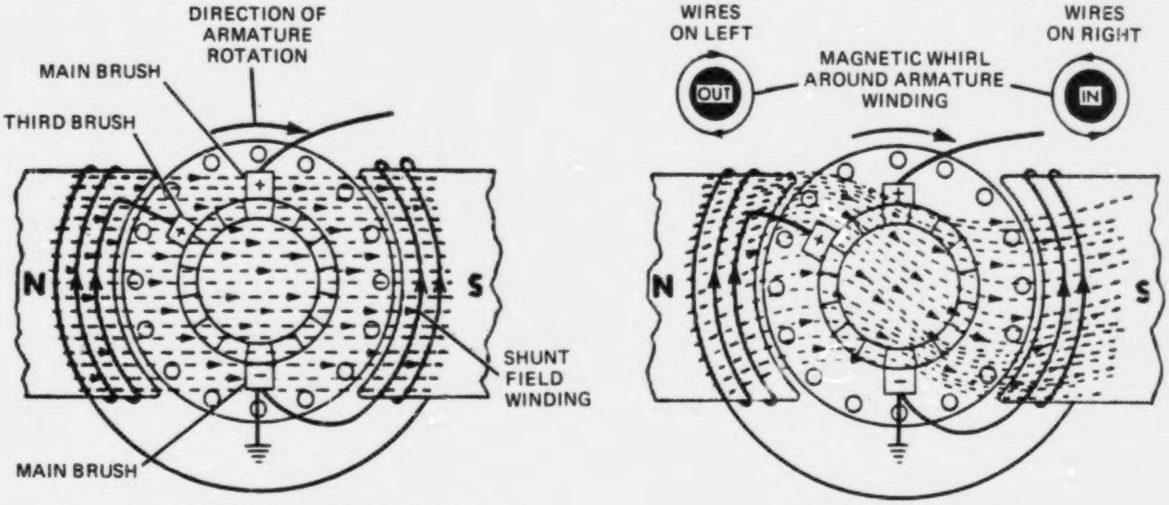
The rheostat is connected to the shunt-winding circuit of the voltage regulator. Its purpose is to permit adjustment of the voltage regulator setting. When all resistance in the rheostat is cut out (by turning the knob), the full generator voltage is imposed in the shunt winding. But when some of the rheostat resistance is cut in, less than full generator voltage is imposed on the shunt winding (part of it being in the rheostat). In the latter case, generator voltage must go higher before voltage regulation commences. Thus, accurate setting of the regulator can be made.

13-15. Third-Brush Regulation (Fig. 13-13). Third-brush regulation is much simpler in operation and less expensive to manufacture than other methods of control. However, it can be used only for relatively small and specialized applications. Generators with this type of control have an extra brush called the third brush, located between the two main brushes.

a. Arrangement. Arrangement of a typical two-pole, third-brush generator is shown in figure 3-13. One end of the shunt-field winding is connected to the third brush, the other end is grounded. Only a part of the total voltage generated is supplied to the field by the third brush.

b. Operation.

(1) When the generator is running at a low speed and little or no current is flowing in the



LITTLE OR NO CURRENT FLOWING
(LOW SPEED)

LARGE CURRENT FLOWING
(HIGH SPEED)

Figure 13-13. Third-Brush Regulation.

TA233552

armature winding, the magnetic field produced by the field windings is approximately straight through the armature from one pole piece to the other. The voltage generated by each armature coil is then practically uniform during the time the coil is under the pole pieces.

(2) As the generator speed and current increase, the armature winding acts like a solenoid coil to produce a cross-magnetic field. The magnetic whirl around the armature winding distorts the magnetic field produced by the shunt-field windings so that the magnetism is not distributed equally under the pole pieces. With this distortion of the magnetic field, the armature coils no longer generate a uniform voltage while passing under the different parts of the pole. Although the voltage across the main brushes remains nearly the same, a greater proportion of this voltage is generated by the coils between the positive brush and the third brush than was generated between them when little current was flowing through the armature winding. This is due to the distortion of the magnetic field, which crowds more magnetic lines of force between the positive and the third brush.

(3) The coils that connect the commutator between the negative and the third brush are in the region of the weakened field and generate a lower proportion of the voltage. The result is a dropping off of the voltage between the negative and third brushes, which is applied to the shunt-field winding, thereby weakening the field strength. As the field strength decreases with increased generator current, the result will be an automatic regulation of the current output.

c. Output.

(1) One of the outstanding characteristics of generators with third-brush regulation is that the output of the generator increases gradually up to an intermediate speed. After this, due to obvious field distortion, the output falls off as the speed continues to increase. At high generator speeds, the output is approximately one-half its maximum value.

(2) In practically all generators that have third-brush regulation, provision is made for changing the output to suit the conditions under which the generator is operated. This can be done by moving the position of the third brush on the commutator. The average voltage applied to the field winding will depend upon the number of armature coils spanned by the brushes that collect the field current. Thus, moving the third brush in the direction of the armature rotation increases the average current delivered to the shunt-field winding and, consequently, the output of the generator. Moving the brush against the direction of armature rotation decreases the output. When this brush is moved, care should be taken to see that it makes perfect contact with the commutator.

(3) Because the third-brush generator depends upon the current flowing through the armature winding to produce the field distortion necessary for regulation, it is obvious that it is current-regulated internally (as distinct from external current regulation). Therefore, it must have a complete circuit available through the battery at all times. Otherwise, regulation would be destroyed and excessive field currents would burn out the generator windings. The generator terminals must be grounded in case the third-brush generator is disconnected from the battery.

13-16. Control of Third-Brush Generator. A fuse is sometimes provided in the field circuit to guard against the possibility of the third-brush generator burning up. When used, it is placed either in the generator end plate or in the regulator control unit. If the battery becomes disconnected, there is a rise in voltage at the generator. This, in turn, sends an abnormally heavy current through the field winding and this field current burns out the fuse. As soon as the fuse is blown, the field circuit is open and no current can flow through it. The generator then merely turns, producing practically no voltage, and does no harm. The third-brush generator provides current regulation only and does not take battery voltage into consideration. In fact, a fully charged battery that has a high voltage actually will get more current from a third-brush generator than a battery that is completely discharged, because the high voltage holds up the voltage at the generator, makes the field stronger, and causes the generator output to increase. This, combined with the varying demands of radio sets and other current-consuming devices, necessitates more accurate regulation than a third-brush generator alone can give.

a. Switch Control. Practically all systems of regulation provide a means for inserting a resistance in series with the third-brush field. A simple way of accomplishing this is shown in figure 13-14. A resistance is mounted on the back of the lighting switch and connected in series with the field. When the lights are off, the generator output current is limited by the resistance in the field circuit. When the lights are turned on, the resistance is shorted so that the generator delivers full current to take care of the additional lighting circuit load. This is just a two-step arbitrary system of regulation, however, that will not meet the varied load requirements of normal vehicle operation.

b. Step-Voltage Control.

(1) The purpose of step-voltage control is to increase or decrease the output of a third-brush generator in accordance with the requirements of the battery and the connected electrical load. It is really a two-stage regulator in which the change from one output to the other is controlled by the generator voltage. The generator voltage is controlled then by battery voltage.

(2) A step-voltage control unit is shown in figure 13-15. A fine-winding voltage coil, connected to the generator armature terminal so that it receives the armature voltage, is the controlling element. Contacts are connected in series with the field terminal and have a resistance unit connected across them. When the battery is fully charged, its voltage raises the generator to such a value that sufficient magnetizing current flows through the fine winding on the control unit to pull the contact points apart. When this happens, the resistance across the contacts is connected in series with the field winding to lower the field strength and, consequently, to reduce the generator voltage and the current output. When the voltage is lowered sufficiently, spring tension will close the contact points and the higher charging rate will be restored.

(3) When there is sufficient electrical load (such as lights, radio, or heater) to require a higher generator output, the contact points will close, because the load will lower the generator voltage and the generator will produce maximum output for the selected position of the third brush and the speed at which it is driven.

c. Vibrating Regulator Control. A vibrating regulator (para 13-13) also can be used with a third-brush generator. Such a regulator is controlled by a voltage coil that operates vibrating contacts. When the battery is discharged, there is insufficient voltage to operate the regulator. The generator output is controlled then only by the third brush. As the battery becomes charged, the voltage of the system will increase and more current will be forced through the regulator coil. The regulator points then begin to vibrate, connecting a resistance in the generator field circuit and cutting down the output to a fairly constant value.

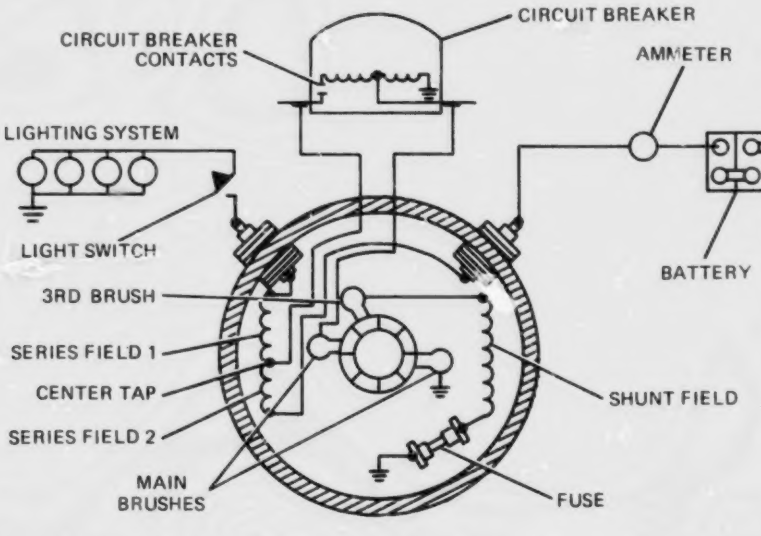


Figure 13-14. Light Switch Control of a Third-Brush Generator.

TA233553

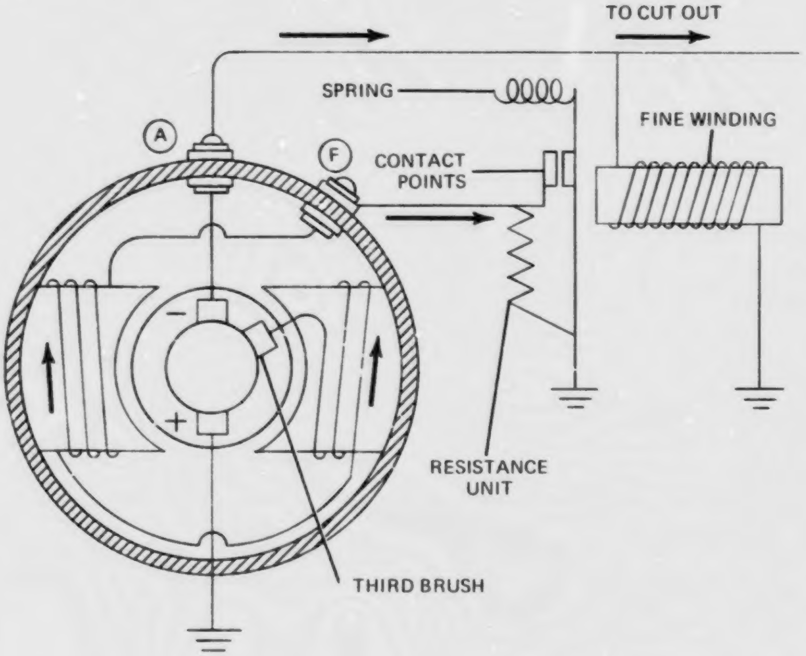


Figure 13-15. Step-Voltage Control of a Third-Brush Generator.

d. Thermostatic Control.

(1) Another type of control for the third-brush generator uses a thermostat blade to control the field strength. If the generator is set to give the greatest possible current to take care of demands during the winter, the battery would be in a constant state of overcharge in warm weather and soon be ruined. The thermostat blade automatically takes care of the changing current demands under different conditions.

(2) The control consists of a bimetal thermostat blade made of a strip of spring brass welded to a strip of nickel steel. The blade warps or bends when heated, due to the greater expansion of the brass side. The blade is set so that a contact on its end is held firmly against a fixed contact at low temperatures. When the temperature rises to approximately 160° to 165°F, the blade bends and separates the contacts.

(3) The thermostat is connected in the third-brush field circuit (fig. 13-16) so that the full field current passes through the thermostat contacts when closed, permitting full current from the generator. After the engine has been run long enough for the high charging rate to heat the generator, the thermostat contacts open (due to the bending of the thermostat blade), causing a resistance unit across the contacts to be connected in series with the third-brush field and thereby reducing the current output. The charging rate is reduced approximately 30 percent when the thermostat contacts are opened.

(4) The chief advantages of thermostatic control are that it gives a large battery-charging rate in cold weather when the efficiency of the battery is lower than in warm weather, and also a larger charging rate when the vehicle is being driven intermittently and the demands on the battery are greater because of frequent use of the starter. This control also prevents the generator and battery from overheating in summer by reducing the charging rate when the temperature rises.

13-17. Split-Series Field Generators (Fig. 13-17).

a. Generator regulation sometimes is accomplished by means of a split-series field. A generator with this method of regulation combines third-brush, reversed-series (differential), and cumulative-compound principles. The

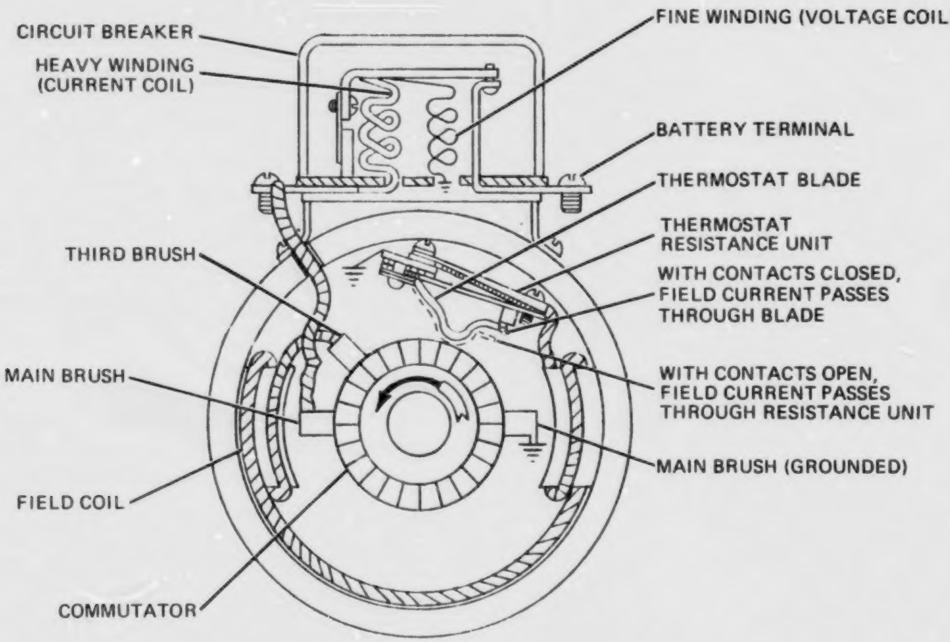

CIRCUIT BREAKER
HEAVY WINDING (CURRENT COIL)
FINE WINDING (VOLTAGE COIL)
BATTERY TERMINAL
THERMOSTAT BLADE
THERMOSTAT RESISTANCE UNIT
WITH CONTACTS CLOSED, FIELD CURRENT PASSES THROUGH BLADE
THIRD BRUSH
MAIN BRUSH
WITH CONTACTS OPEN, FIELD CURRENT PASSES THROUGH RESISTANCE UNIT
MAIN BRUSH (GROUNDED)
FIELD COIL
COMMUTATOR

Figure 13-16. Thermostatic Control of Third-Brush Generator.

series-field winding is divided so that the generator output is changed according to the load.

b. With lights off, no current flows through one part of the series field (1, fig. 13-17). The current going to the battery flows through the remainder of the series field (2, fig. 13-17) in the opposite direction to the shunt-field current. This weakens the total field strength, keeping the generator output down for the delivery of a reasonable charging rate.

c. When the lighting switch is closed, the entire lighting current flows through section 1 of the series field in the same direction as the shunt

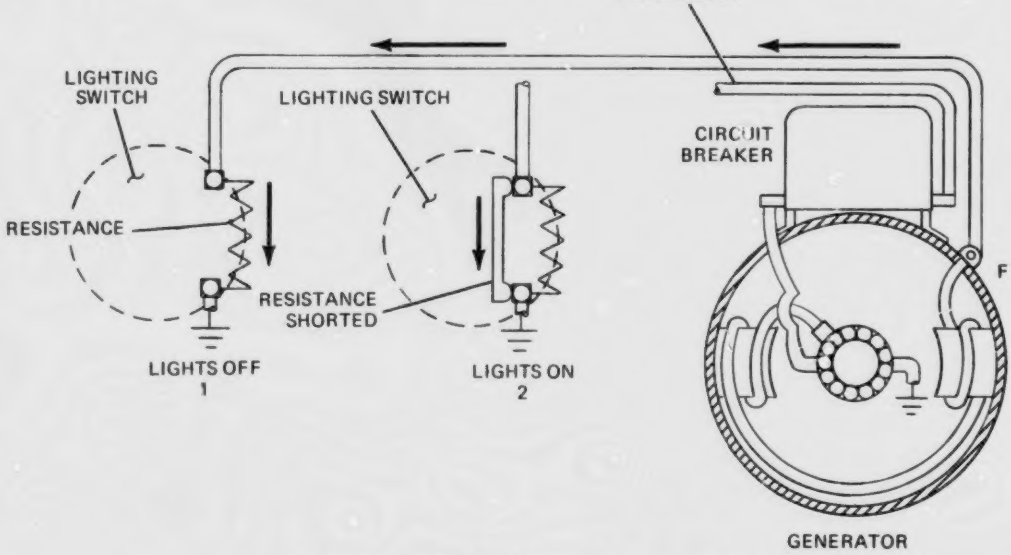

TO AMMETER
LIGHTING SWITCH
LIGHTING SWITCH
CIRCUIT BREAKER
RESISTANCE
RESISTANCE SHORTED
F
LIGHTS OFF
1
LIGHTS ON
2
GENERATOR

Figure 13-17. Split-Series Field Regulation.

TA233555

279

BEST COPY AVAILABLE

field. The strength of the field is thereby increased, giving a higher generator output to take care of the lighting load.

d. If the lights are turned on before the generator circuit breaker closes, the entire lighting current is supplied by the battery. This current then flows through all of the series field, instead of through section 1 only, in the same direction as the shunt field, making the total field strength still greater. This will build up the generator voltage to close the circuit breaker. The entire current output of the generator that passes through the circuit breaker flows to the center tap of the series field, where it divides. Part of the current then flows in one direction through to the battery and the remainder flows to the lights.

e. As soon as the circuit breaker closes, the generator begins to pick up the lighting load. This lessens the drain on the battery and thereby reduces the current flowing through section 2 of the series field. When the generator output just equals the lighting current, the current in section 2 is zero and, as the generator output increases further, current begins to flow in the reverse direction through section 2 to the battery. This tends to weaken the field built up by the shunt winding and section 1 of the series winding. By obtaining the proper relationship between the shunt winding and the two sections of the series winding, results quite similar to those obtained from voltage regulation are secured, and the battery is kept in a charged condition.

f. The charging rate of the split-series field generator may be adjusted by shifting the third brush as in the regular third-brush generator. In some generators of this type, separate coils are used for the two sections of the series field. In others, the two sections are combined into one coil. Generators of this type do not have standard connections and must not be confused with the ordinary third-brush generator. Neither terminal should be grounded under any circumstances.

13-18. Paralleling Generators.

a. General. Some military vehicles have two separate powerplants, each with its own generator and regulator working into a common set of batteries. Certain combat vehicles have a single powerplant, but they also carry an auxiliary generator. Where two generators are working in a single set of batteries and a single electrical system, the problem of paralleling exists. That is, the two generators must be connected in parallel. Unless special provision is made, trouble may result if two generators are parallel. The reason for this is that one generator may attempt to carry most or all of the load while the other generator might use current or act like a motor. The problem is further complicated if one of the generators varies in speed (as the unit on the powerplant might).

b. System Description. To provide effective paralleling, each of the voltage regulators contains an additional paralleling winding. These windings become connected to each other through two paralleling relays when both generators are operating. With this condition, the paralleling windings can increase the voltage (and thus the output) of the generator that is producing more than its share. Therefore, the two generators can be kept in step.

13-19. Generator System – Main and Auxiliary Generators.

a. General. A wiring circuit of a combat vehicle using a main and auxiliary generator is shown in figure 13-18 in schematic form. This system uses two generators, two carbon-pile regulators, plus various relays and switches. The following chart identifies the circuits in figure 13-18.

CIRCUIT	CIRCUIT NAME
1	Main Generator Feed
2	Main Gen Positive Line
7	Battery Ground
10	Instrument Panel Feed
61	Auxiliary Generator Field
62	Aux Gen Positive Line
65	Auxiliary Engine Starter
81	Battery – Positive Line
421	Aux Eng Fuel Cutoff Valve
422	Aux Eng Magneto Ground
459	Master Relay Control
459B	Master Relay Feed
478A	Aux Gen Equalizing
478M	Main Gen Equalizing
506	Main Gen Warning Light
508	Aux Gen Warning Light

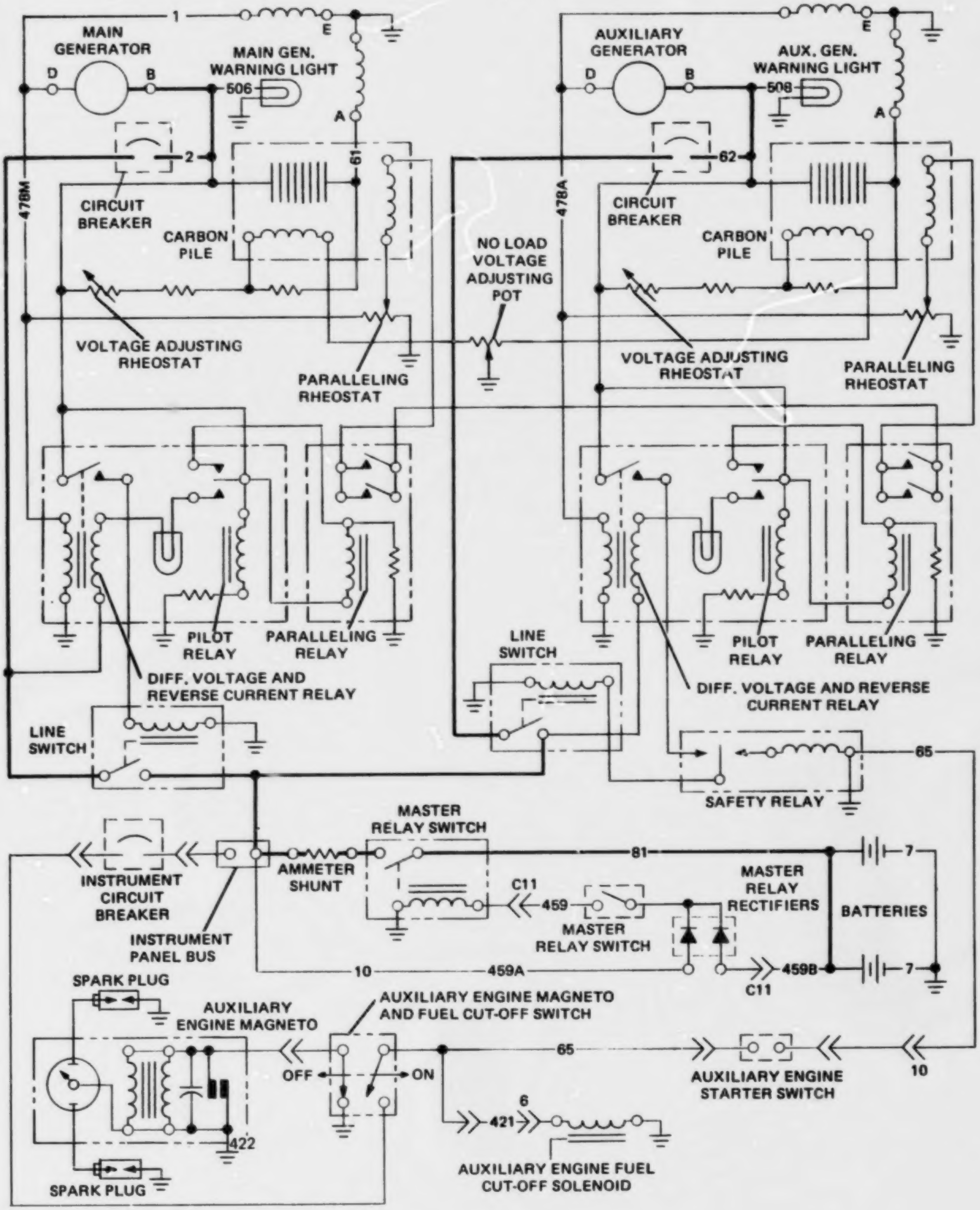

1
E
MAIN GENERATOR
D
B
MAIN GEN. WARNING LIGHT
506
A
2
61
478M
CIRCUIT BREAKER
CARBON PILE
VOLTAGE ADJUSTING RHEOSTAT
PARALLELING RHEOSTAT
PILOT RELAY
PARALLELING RELAY
DIFF. VOLTAGE AND REVERSE CURRENT RELAY
LINE SWITCH
AUXILIARY GENERATOR
AUX. GEN. WARNING LIGHT
508
62
478A
NO LOAD VOLTAGE ADJUSTING POT
CIRCUIT BREAKER
CARBON PILE
VOLTAGE ADJUSTING RHEOSTAT
PARALLELING RHEOSTAT
PILOT RELAY
PARALLELING RELAY
DIFF. VOLTAGE AND REVERSE CURRENT RELAY
LINE SWITCH
SAFETY RELAY
65
MASTER RELAY SWITCH
81
7
INSTRUMENT CIRCUIT BREAKER
AMMETER SHUNT
C11
459
MASTER RELAY RECTIFIERS
BATTERIES
MASTER RELAY SWITCH
INSTRUMENT PANEL BUS
10
459A
459B
C11
7
SPARK PLUG
AUXILIARY ENGINE MAGNETO
AUXILIARY ENGINE MAGNETO AND FUEL CUT-OFF SWITCH
OFF
ON
65
AUXILIARY ENGINE STARTER SWITCH
10
6
421
422
AUXILIARY ENGINE FUEL CUT-OFF SOLENOID
SPARK PLUG

Figure 13-18. Main and Auxiliary Generators.

TA233556

b. Generator. The generator is a shunt generator with a maximum output of 150 amperes, and is used with a 24-volt battery set. The generator contains an additional field winding of a few turns of very heavy wire through which the entire generator output passes. This is a series winding. It is wound so that its magnetic field opposes the magnetic field from the shunt windings. This acts as a current-limiting device because the higher the output, the greater the opposition from the series-winding magnetic field. When the output reaches the rated maximum, the series-winding field is so strong that it effectively prevents any further increase in output. More increases would strengthen the series-winding field, thus further opposing the shunt-winding field and causing a decreased total field and, consequently, a dropoff of output. This series-field winding in the generator also plays an important part in the operation of the regulators and certain relays in the control system (para c and d, below).

c. Pilot Relay. There is a pilot relay for each generator. Because both operate the same, the one used with the main generator will be discussed. It contains a shunt winding that is connected across the main generator terminals. In addition, it has two sets of contacts: an upper set and a lower set. The upper set is used in conjunction with the paralleling system, so consider the lower set first. This lower set is open when the generator is not operating. But when the generator begins to run and its voltage increases sufficiently to charge the battery, then the lower set closes. The shunt winding in the relay produces this action because, with sufficient voltage, it has a strong enough magnetic pull to pull down the relay armature and close the lower contacts. When the lower contacts close, this causes the differential-voltage-and-reverse-current relay to operate.

d. Differential-Voltage-and-Reverse-Current Relay.

(1) *Closing.* When the pilot relay closes its points, one of the windings in the differential-voltage-and-reverse-current relay becomes connected between the insulated battery terminal and the installed generator terminal. If the generator voltage is greater than the battery voltage, the difference (or differential) between the two causes current to flow in the winding (which is called the differential-voltage winding). As this current flows, a magnetic field is produced that pulls the relay armature down and causes relay contacts to close. When the relay contacts close, the line-switch winding is connected across the generator so that it closes, thereby directly connecting the generator to the battery.

(2) *Opening.* With the relay and line switch closed so the generator charges the battery, current flows through the battery and back to the generator by means of ground wire and the series winding in the generator field. Because the current is flowing through the series winding, there is a voltage difference between the two ends of this winding. This voltage varies with the rate of current. With a high generator output, a high current is flowing and the voltage across the series winding is greater. This voltage is applied to the differential-voltage-and-reverse-current relay. When the generator is charging and the relay is closed, this voltage is imposed across a second winding in the relay (the reverse-current winding) in such a direction as to help the differential-voltage winding hold the relay contacts closed. But when the generator voltage falls below the battery voltage, the battery begins to discharge through the generator. In other words, the current reverses. This means that the current in the series-field winding, and thus the voltage across the series-field winding, also reverses. The resultant reverse voltage, which is applied to the reverse-current winding, causes the magnetic field of this winding to reverse. This winding then no longer helps the differential-voltage winding, but opposes it. As a result, the total magnetic field is so weakened that the relay armature is pulled up by its spring tension and the contacts open. This then opens the line switch winding circuit so the line switch opens. This disconnects the generator from the battery.

e. Line Switch. The line switch is a simple magnetic switch. When its winding is electrically energized, it pulls the armature down so the switch is closed. When the winding is disconnected, the spring pressure under the armature moves the armature up so the switch opens.

f. ParallelingRelays.

(1) *Connections.* In operation, the contacts of the paralleling relays are connected in

282

series with the paralleling windings in the two voltage regulators and to the two series-field windings in the two generators. Whenever a generator begins to charge, the armature on the pilot relay moves from the upper to the lower position, opening the upper and closing the lower contacts. When the upper contacts are closed (meaning that the generator is not charging), the paralleling relay winding is shorted through them and no paralleling relay action can take place. But when the pilot relay opens these upper contacts and closes the lower contacts, the winding of the paralleling relay becomes connected across the generator. Now, generator voltage can energize the winding and cause the paralleling relay to close its contacts. Only one paralleling relay will be actuated if only one generator is operating. This means that no paralleling can take place. But when both generators are operating so that both paralleling relays are in action, then the contacts of the relays, the paralleling windings in the regulators, and the series-field windings in the generator are all in series.

(2) *Operation.* When all are in series, current will flow in the circuit if one generator is putting out more current than the other. To understand how this might be, refer to figure 13-19, which is a simplified sketch of the generator series-field windings and the regular paralleling windings connected in series. The paralleling relay contacts are not shown here because they are closed and are therefore a part of the circuit. Suppose that the main generator is putting out more current than the auxiliary generator. This means that more current flows through the series-field winding of the main generator than through the series-field winding of the auxiliary generator. Under these conditions, there will be a greater voltage across the main generator series-field winding. This means that current will flow from this winding, through the paralleling windings, and the auxiliary generator series-field winding. The current flow through the paralleling windings in the regulators helps the regulating winding in one regulator and opposes the regulating winding in the other. It helps in the main generator regulator; this means that the spring pressure on the carbon-pile armature is lightened further so that the carbon-pile resistance increases, cutting down the main generator output. On the other hand, the paralleling winding in the auxiliary generator regulator opposes the regulating winding. This means that the spring pressure on the carbon-pile armature is increased. Carbon-pile resistance is reduced and the auxiliary generator output goes up.

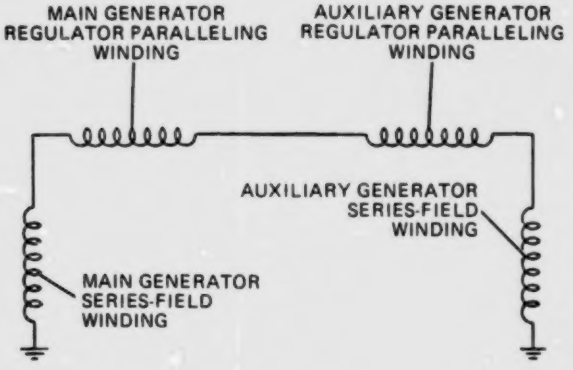

MAIN GENERATOR REGULATOR PARALLELING WINDING
AUXILIARY GENERATOR REGULATOR PARALLELING WINDING
AUXILIARY GENERATOR SERIES-FIELD WINDING
MAIN GENERATOR SERIES-FIELD WINDING

Figure 13-19. Paralleling Relays.

(3) *Paralleling.* With paralleling, if one generator tries to produce more output than the other, its output is cut down immediately while the output of the low generator is increased. The action is entirely automatic once the system has been adjusted correctly. In order to achieve adjustment, the voltages of the two carbon-pile regulators must first be set, then the voltages perfectly balanced by means of the no-load voltage-adjusting potentiometer, or pot. Finally, the two paralleling rheostats must be adjusted. All these adjustments must be made by authorized personnel and according to instructions supplied in the applicable technical manual.

g. Regulators. The carbon-pile regulators, one for each generator, operate on generator voltage (para 13-16). A simplified sketch of one carbon-pile regulator circuit is shown in figure 13-20 (paralleling winding not shown). Some special features of this circuit will be of interest. The carbon pile is connected between the insulated generator brush and the generator shunt field. The regulator winding is connected across the generator brushes so that full generator voltage is imposed on it. It therefore regulates on generator voltage as explained in paragraph 13-16. There is a voltage-adjusting rheostat connected in series with the winding so that voltage adjustment can be made. In addition, the circuit goes to ground through an adjustable resistor called a potentiometer. The potentiometer permits accurate balancing of the two voltage regulator settings.

TA233557

283

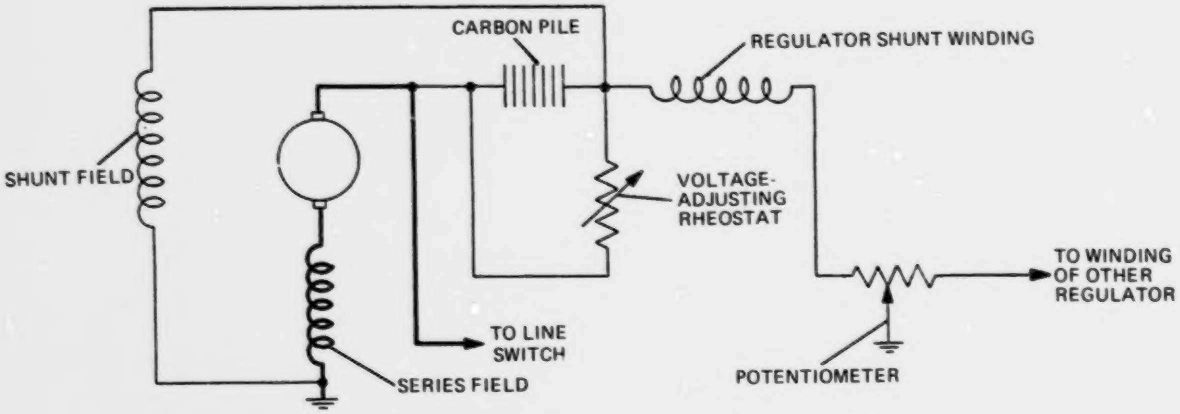


Figure 13-20. Carbon-Pile Regulation of Generators.

For instance, if one regulator is slightly higher than the other, but both are within specifications, balance can be achieved by turning the potentiometer knob slightly. This puts more resistance into one regulating winding circuit and takes it out of the other, thus achieving the desired results.

Section III. AC GENERATOR SYSTEMS

13-20. General. Most of the military vehicles are now equipped with an ac charging system. The reason for changing to the ac system is that an alternator is capable of producing a higher voltage at idle speed, whereas a dc generator produces very little voltage at idle speed. Many of the military vehicles are equipped with radios, firing devices, and other high-current-drawing equipment. When this equipment is in operation and the vehicle's engine is at a low rpm, a dc generator will not produce the required current and voltage to keep the batteries charged and supply the current required to operate the accessories properly.

13-21. The Basic Alternator.

a. Construction (Fig. 13-21). The alternator is composed of the same basic parts as a dc generator. There is a field that is called a rotor and a generating part known as the stator. The purpose of the alternator is to produce more power and operate over a wider speed range than that of a generator. Because of this, the construction of the functional parts is different. The stator is the section in which the current is induced. It is made of a slotted laminated ring with the conductors placed in the slots. The current generated in the windings is transferred to the rest of the system through three stationary terminals.

b. Rectifier Bridge (Fig. 13-22). The ac generator produces alternating current at its output. As stated in paragraph 13-6, this is unacceptable for an automotive electrical system. The ac generator is fitted with a rectifier bridge to convert the output to dc. If the two output wires of a basic ac circuit are each fitted with a silicon diode (para 11-5), the alternating current can be given one direction and thus be changed to direct current. To change current direction, use diodes that allow current flow toward the alternator on one wire (positive) and away from the alternator on the other wire (negative). Because most automotive alternators have three outputs (three-phase stator), the rectifier bridge will consist of six diodes (three positive and three negative). The diodes will be connected so that they combine the three ac outputs of the alternator into one dc output.

13-22. Comparison to a DC Generator.

a. Advantages.

(1) The ac generator is configured opposite to the dc generator. The current is produced in the stator, which does not rotate. This compares with the dc generator that produces current from its armature, which must transmit its output through brushes. This means that the brushes must be very large and, therefore, will wear out

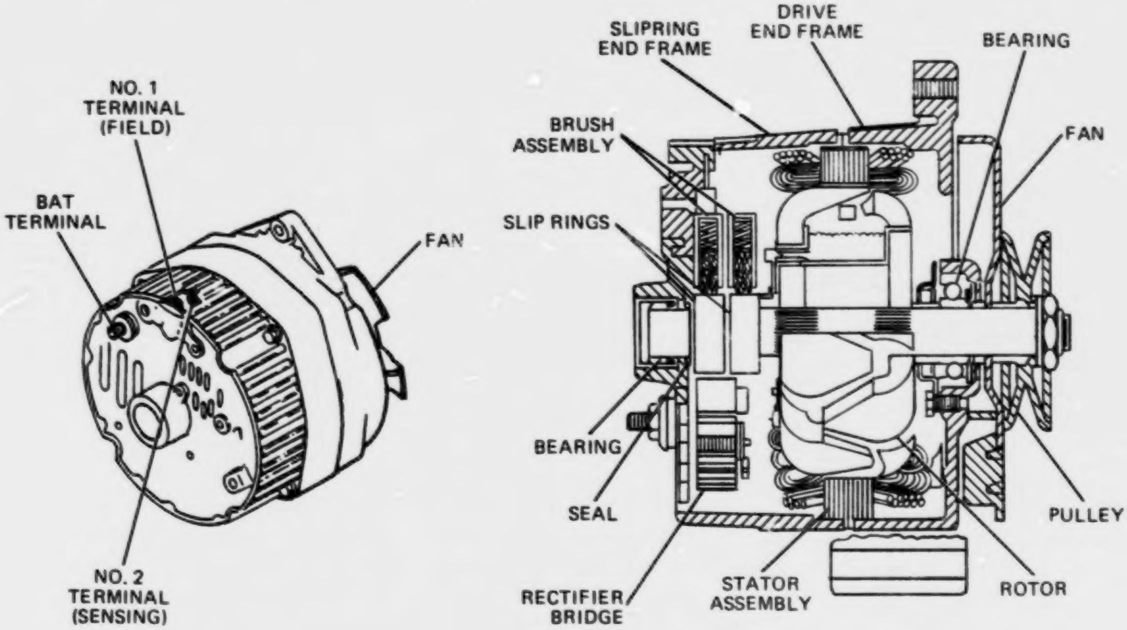


Figure 13-21. Typical Alternator.

quickly due to arcing caused by the large current carried by them.

(2) The rotating field in the ac generator is much lighter and less susceptible to centrifugal force. Because the brushes must only transmit field current, they can be much smaller and will last longer due to less arcing.

(3) The ac generator uses smooth sliprings on its rotor that produce very little arcing during use. This compares with the segmented commutator of the dc generator, which causes large efficiency losses due to drag and arcing.

(4) The ac generator is much smaller and lighter than its dc counterpart.

b. Disadvantages.

(1) The ac generator requires electronic rectification through the use of silicon diodes. Modern rectifier bridges, though extremely durable under normal conditions, are extremely sensitive to accidental polarity reversal. This can result from jump starting, battery charging, and battery installation.

(2) The ac generator does not retain residual magnetism in its field. Because of this, an ac generator-equipped vehicle cannot be push started with a completely dead battery.

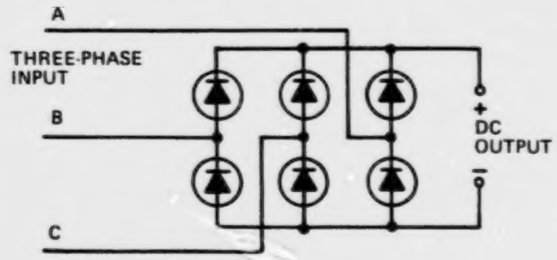
c. Comparison of Output Characteristics. It can be seen from figure 13-23 that the dc generator has a much narrower speed-producing range than the ac generator. The initial startup is at a much higher rpm, which is undesirable for vehicles that operate mostly in low-speed ranges. As high speeds are reached, the dc generator output will fall below its rated output largely due to the brushes bouncing on the commutator segments, causing poor commutation.

13-23. The Automotive Alternator.

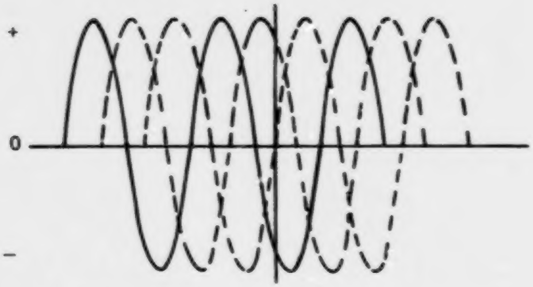
a. The Basic Alternator. A basic alternator would consist of one winding or loop in the stator and a single pair of poles in the rotor (fig. 13-24). When the rotor of this machine is turned through 360 degrees, it will induce a single cycle of ac just as the simple generator armature did.

b. Rotor Design (Fig. 13-25). The rotor is designed with two pole pieces that sandwich the

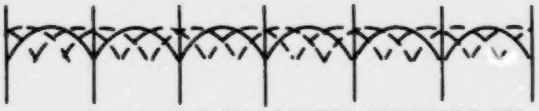
TA233560


A
THREE-PHASE INPUT
B
C
+
DC OUTPUT
−

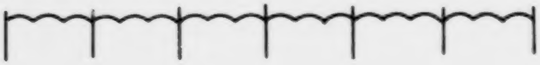
DIODE CONFIGURATION IN ALTERNATOR



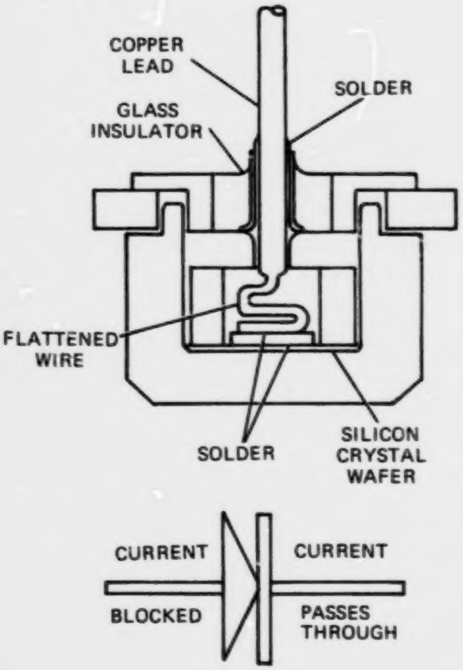
WAVE PATTERN PRIOR TO BEING RECTIFIED



AC CURRENT CHANGED TO DC BY RECTIFIERS



RESULTANT DIRECT CURRENT VOLTAGE


COPPER LEAD
GLASS INSULATOR
SOLDER
FLATTENED WIRE
SOLDER
SILICON CRYSTAL WAFER
CURRENT BLOCKED
CURRENT PASSES THROUGH

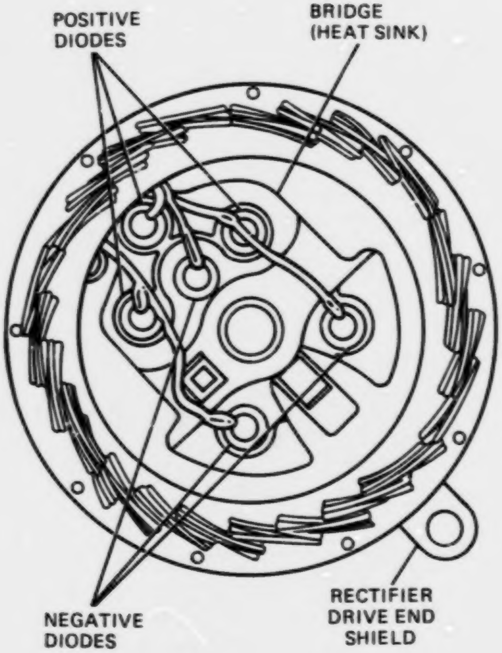

POSITIVE DIODES
BRIDGE (HEAT SINK)
NEGATIVE DIODES
RECTIFIER DRIVE END SHIELD

Figure 13-22. Diode Arrangement Rectifier Bridge.

TA233559

286

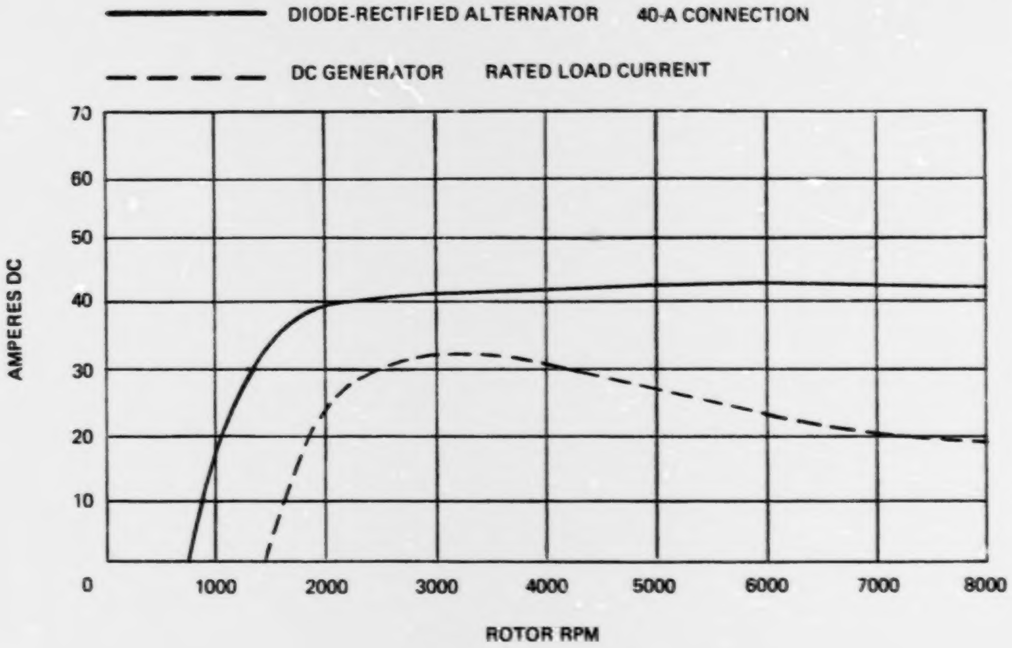


Figure 13-23. Comparison for Outputs of AC and DC Generators.

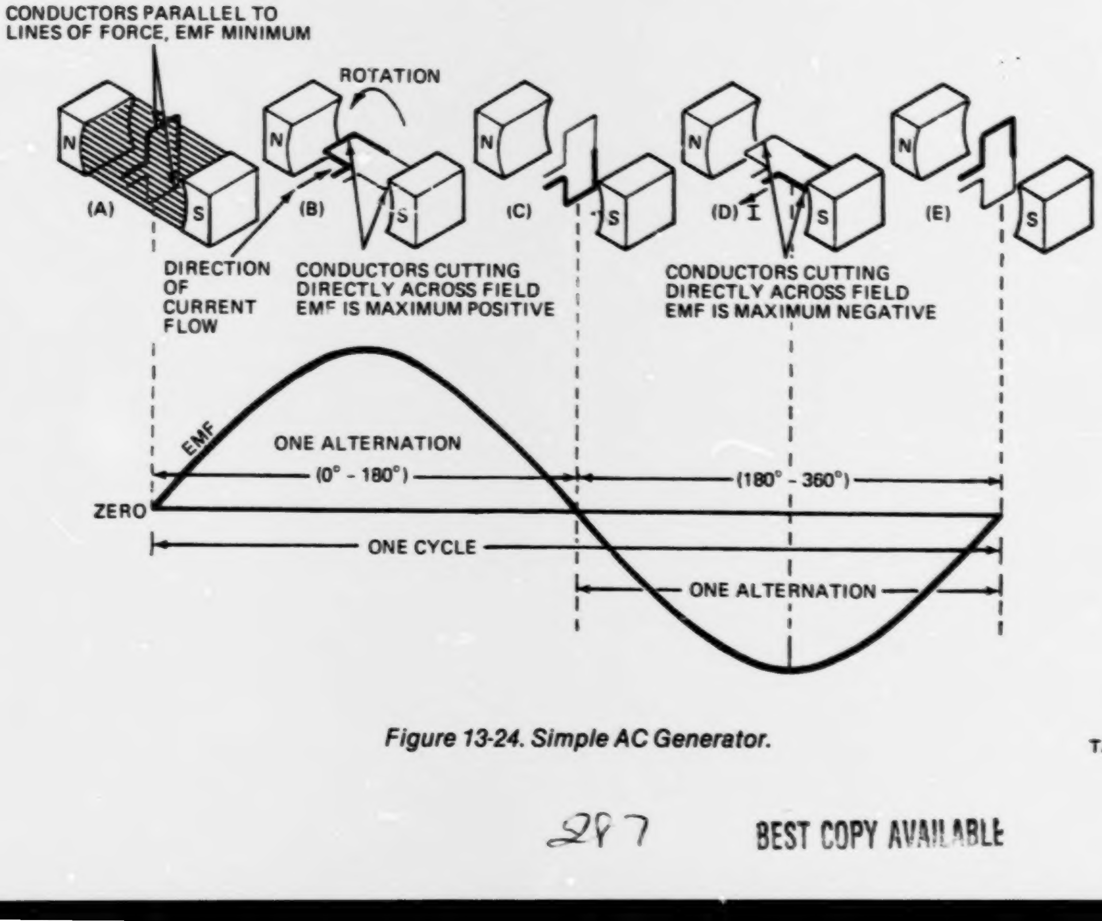

CONDUCTORS PARALLEL TO LINES OF FORCE, EMF MINIMUM
ROTATION
N
S
(A)
(B)
(C)
(D)
(E)
I
DIRECTION OF CURRENT FLOW
CONDUCTORS CUTTING DIRECTLY ACROSS FIELD EMF IS MAXIMUM POSITIVE
CONDUCTORS CUTTING DIRECTLY ACROSS FIELD EMF IS MAXIMUM NEGATIVE
EMF
ONE ALTERNATION
(0° - 180°)
(180° - 360°)
ZERO
ONE CYCLE
ONE ALTERNATION

Figure 13-24. Simple AC Generator.

TA233561

287

BEST COPY AVAILABLE

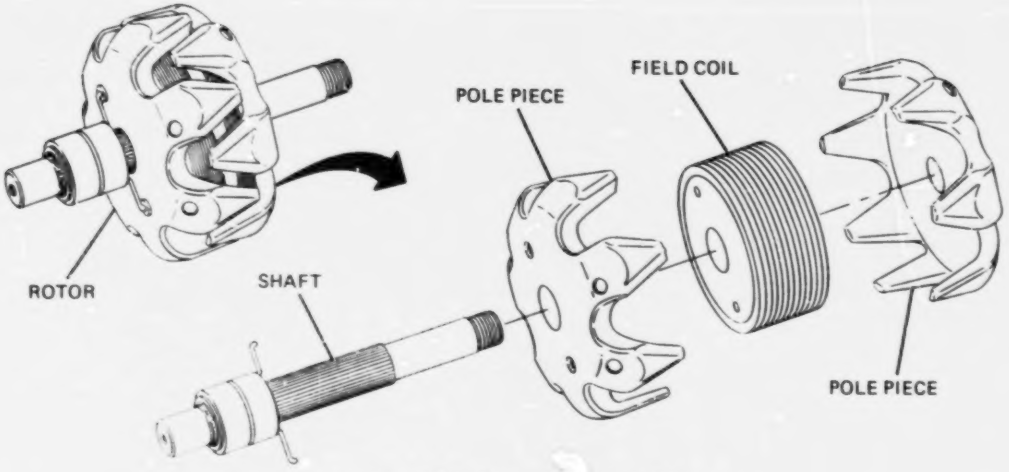


Figure 13-25. Rotor Construction.

field winding on the shaft. Each pole piece has fingerlike projections. When the rotor is assembled, the projections interlock with each other. The pole pieces form north and south magnetic poles. The core of the rotor contains the axially wound field winding which is made of varnish-insulated copper wire. Each end of the field winding is connected to an individual slipring.

c. Stator Design (Fig. 13-26). The stator is designed with three separate windings so that it produces three separate ac currents. This is known as three-phase output. Each winding is in the form of loops that are spaced at intervals on the frame. The windings then are arranged so that they are offset from each other. The three windings are all tied together at one end to form what is known as a wye wound stator.

d. Rotor-to-Stator Relationship (Fig. 13-27). The rotor is synchronized to the stator; that is, when one north pole projection is alined with one of the loops of one-phase winding loop, the other north pole projections will also aline with the other loops of that phase winding. This sequence of alinement between the rotor projections is necessary for operation. If one-phase winding was being acted on by a negative pole projection at one loop and a positive pole projection at another loop, the two loops would cancel each other out and no current would be generated.

13-24. Common Alternator Designs. The following are brief descriptions of various configurations of alternators.

a. Wound-Pole Alternator. Figure 13-28 illustrates the configuration of a typical wound-pole alternator with rotating field. Alternate

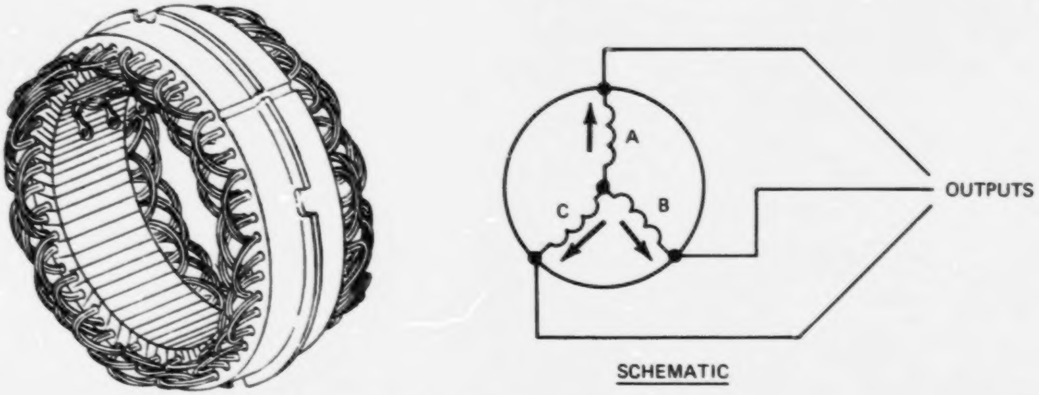


Figure 13-26. Stator Construction.

TA233562

288

BEST COPY AVAILABLE

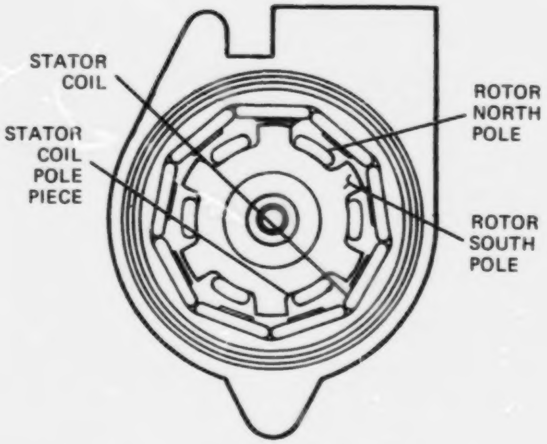

STATOR COIL
STATOR COIL POLE PIECE
ROTOR NORTH POLE
ROTOR SOUTH POLE

Figure 13-27. Rotor-to-Stator Relationship.

polarity occurs on successive poles. Pole excitation current is obtained through sliprings. The advantages of the wound-pole alternator are a wide speed range: output current windings are stationary, and sliprings carry low field excitation current. The following are disadvantages of the wound-pole alternators: Brushes and sliprings wear, are affected by contamination, produce contaminating carbon dust, may cause voltage modulation, and are not reliable for high-temperature, high-altitude, or high-speed applications. Brush arc is an explosion hazard; fuel or oil cannot be used safely as a coolant. The rotor winding is hard to cool and is relatively unreliable in high-speed or rough-drive applications that cause stress on rotor windings and insulation. The wound-pole alternator has an extensive history of development, but is best suited for low-speed applications in a limited range of environments.

b. Lundell Alternator. The Lundell rotor, as shown in figure 13-29, develops a field by placing the excitation windings around the axis of the rotor shaft, resulting in each end of the shaft assuming a polarity. Coupled to each end are interspaced fingers forming opposite polarities that provide an alternating field when rotated. Field excitation is achieved through slipring conduction. The following are advantages of the Lundell rotor. This rotor has a simple rotor winding construction and stationary output current windings. The disadvantages of the Lundell rotor are windage (air resistance) losses and the use of sliprings and brushes.

c. Lundell Inductor. This generator type differs from the previously described Lundell type, in

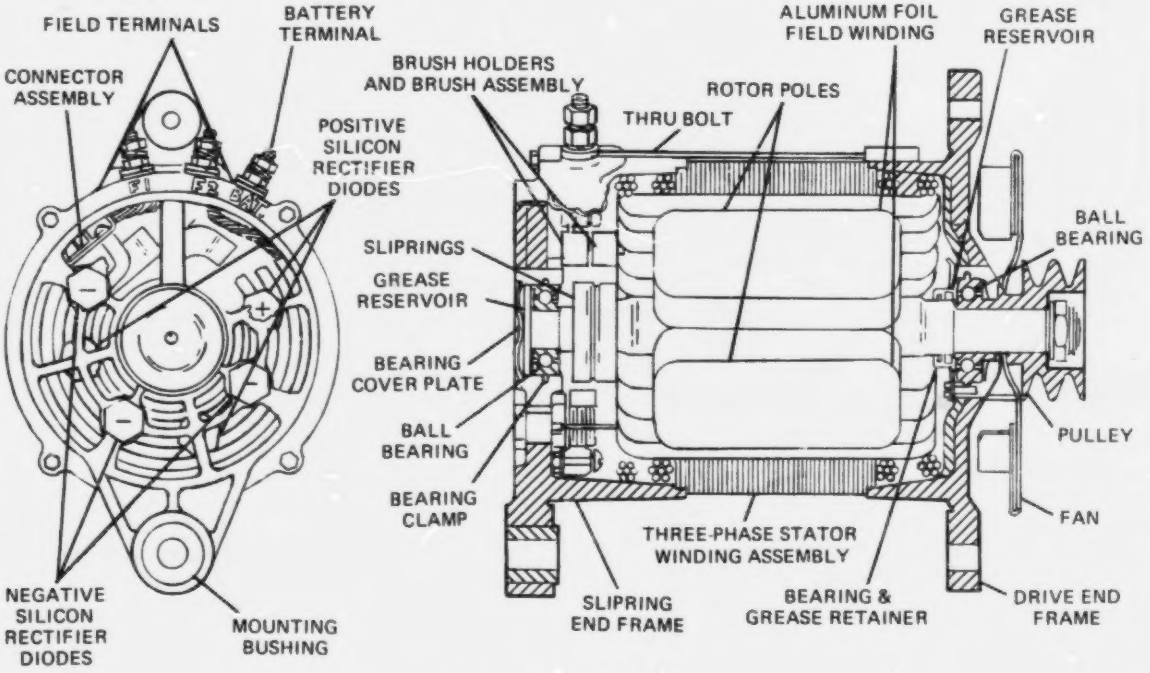

FIELD TERMINALS
BATTERY TERMINAL
CONNECTOR ASSEMBLY
POSITIVE SILICON RECTIFIER DIODES
F1
F2
BAT
NEGATIVE SILICON RECTIFIER DIODES
MOUNTING BUSHING
BRUSH HOLDERS AND BRUSH ASSEMBLY
THRU BOLT
ROTOR POLES
ALUMINUM FOIL FIELD WINDING
GREASE RESERVOIR
BALL BEARING
SLIPRINGS
GREASE RESERVOIR
BEARING COVER PLATE
BALL BEARING
BEARING CLAMP
PULLEY
FAN
THREE-PHASE STATOR WINDING ASSEMBLY
SLIPRING END FRAME
BEARING & GREASE RETAINER
DRIVE END FRAME

Figure 13-28. Wound-Pole Alternator.

TA233563

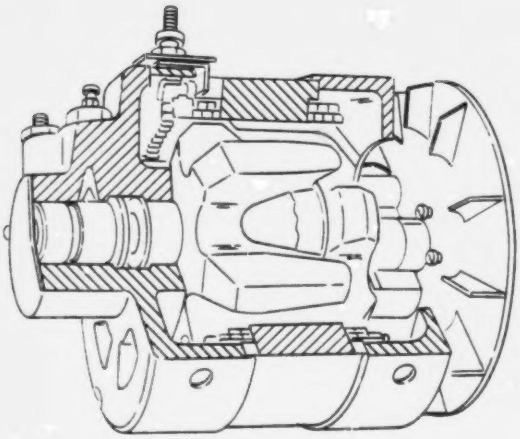


Figure 13-29. Lundell Alternator.

that the rotor contains no windings. Excitation is induced in the rotor poles by stationary field coils located at the ends of the rotor. This results in the elimination of sliprings and rotating windings. Further advantages can be obtained by casting a nonmagnetic material around the pole fingers, thus producing a smooth rotor with low windage losses and high speed capability. An inherent design requirement of this stationary field arrangement is the inclusion of an auxiliary air gap in the magnetic circuit. This requires greater field current for excitation. Figure 13-30 illustrates construction features. There are a variety of advantages to a Lundell inductor.

There are no slipring wear or contamination problems, and the unit is inherently explosion proof. The rotor can be solid and permanently balanced. All windings are stationary and readily accessible for cooling. The low rotor mass reduces bearing loads and permits rapid acceleration. The bearing center-to-center distance is minimized by the elimination of sliprings, and this, combined with a large shaft diameter, permits high-speed operation. The field windings are simple, bobbin-wound coils permitting short mean turn length. The only disadvantage is that extra air gaps in the magnetic circuit require increased excitation power.

d. Inductor Alternator. An inductor alternator employs a fixed, nonrotating field coil that induces excitation in the central portion of the rotor as if it were a solenoid. Each end of the rotor assumes a polarity. A multilobed segment is attached to each end of the rotor. The segment varies the reluctance in the magnetic circuit as it rotates. As a result, the fixed stator poles experience a variation in magnetic strength or coupling and produce a resulting output voltage in the stator coils. In contrast to other types of generators, the iron does not experience a flux reversal. Consequently, there is only a 50-percent utilization of the iron in the stator. Figure 13-31 illustrates typical construction of the inductor alternator. The advantages of an inductor alternator are easier winding construction for field and stator coils; simplified cooling; it is brushless; and it has an integral solid rotor without windings that permits high-speed operation. The disadvantages of an inductor alternator are that it has less than 50 percent use of iron, resulting in a heavier unit and the increased total air gap in the magnetic circuit requires more excitation.

e. Brushless-Rotating Rectifier. Another means for eliminating brushes and sliprings is found in the rotating rectifier type of alternator. The machine consists of five main functional elements. These include a stator-mounted exciter field, the exciter armature, a main rotating field, the main output stator windings, and the output rectifier assembly.

The exciter field induces alternating current in the rotating armature and the output is rectified and directly coupled to the rotating main field, which excites the stator-mounted output windings. With this arrangement, a small amount of exciter field excitation can be amplified in the exciter stage to supply a high level of main field current. A diagram of elements is shown in figure 13-32, along with a cross section through the alternator. The advantages of the brushless rotating rectifier are that it is brushless and a low exciter field current permits a low-level regulator. However, the disadvantages of the brushless-rotating rectifier are that a wound rotor limits top speed, multiple windings contribute to complexity and cost, a large number of heat-producing rotating elements increases cooling requirements, and a large magnetic circuit limits response.

13-25. Cooling Generators. The common methods used for cooling generators use heat transfer by airflow or oil circulation. Each has its particular application based on their advantages and disadvantages.

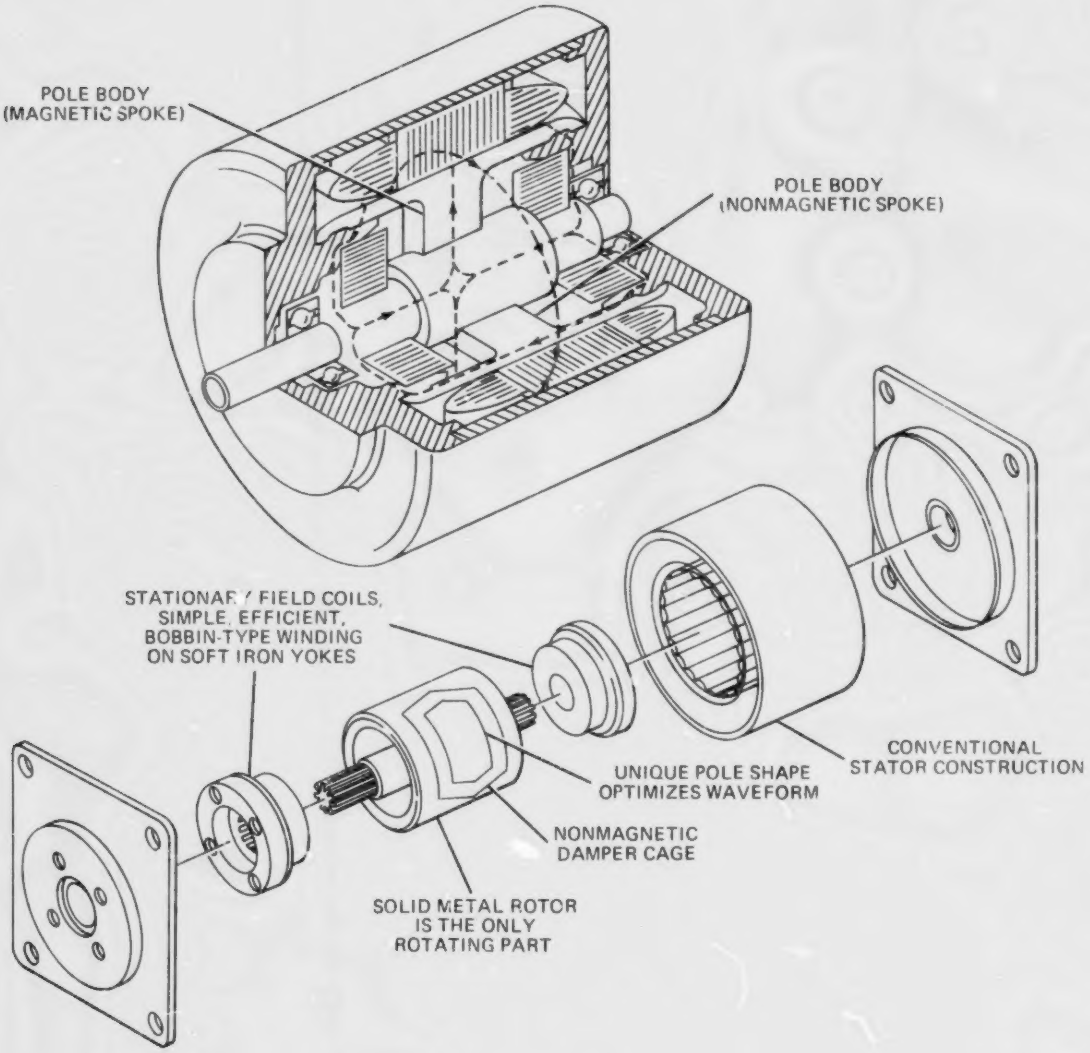

POLE BODY
(MAGNETIC SPOKE)
POLE BODY
(NONMAGNETIC SPOKE)
STATIONARY FIELD COILS, SIMPLE, EFFICIENT, BOBBIN-TYPE WINDING ON SOFT IRON YOKES
CONVENTIONAL STATOR CONSTRUCTION
UNIQUE POLE SHAPE OPTIMIZES WAVEFORM
NONMAGNETIC DAMPER CAGE
SOLID METAL ROTOR IS THE ONLY ROTATING PART

Figure 13-30. Lundell Inductor.

a. Air Cooling (A, Fig. 13-33). In tank-automotive applications, air cooling is the most common method. The usual arrangement consists of a fan that forces air through the alternator to cool the rotor, stator, and rectifier. The major advantage of air cooling is that the generator and cooling are self-contained, drawing air from the environment. However, fan power requirements can become excessive at high speeds because fan designs usually are structured to provide sufficient cooling at the lowest speed corresponding to rated output. Fan power at high speeds then appears as a severe reduction in generator efficiency. Another factor is that, unless it is filtered, cooling air can deliver abrasive particles, water, or other substances to the generator interior. Furthermore, rotor and stator design must permit unrestricted passage of air through the generator. This can be accomplished by designing passages through the rotor and stator. However, roughness in the surface of the rotor contributes to windage losses, further affecting unit efficiency.

b. Oil Cooling (B, Fig. 13-33). Oil cooling features a transfer of alternator heat into the circulating oil flow, followed by cooling of the hot oil in a heat exchanger. The oil supply can be

TA233565

291

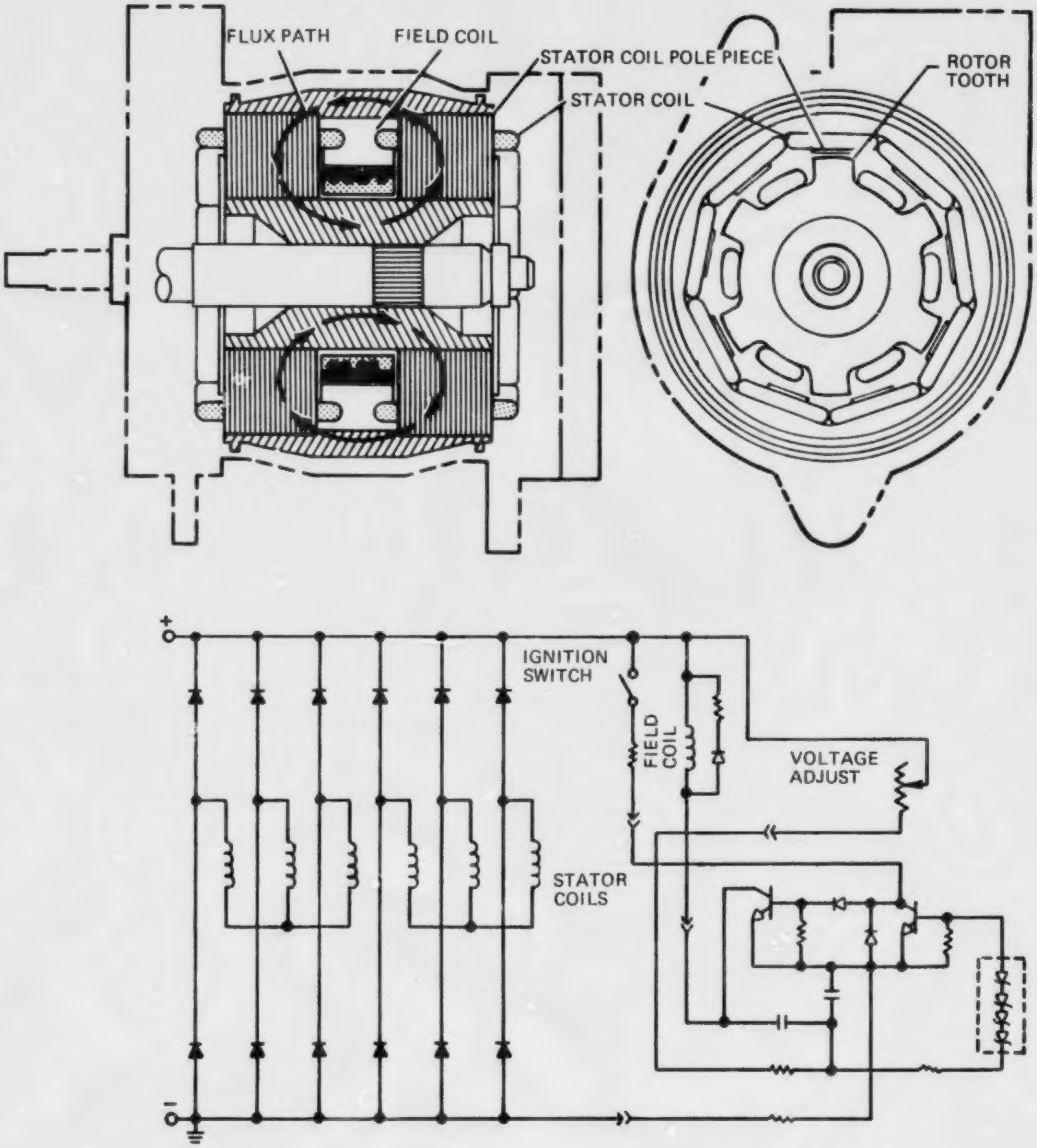

FLUX PATH
FIELD COIL
STATOR COIL POLE PIECE
STATOR COIL
ROTOR TOOTH
+
IGNITION SWITCH
FIELD COIL
VOLTAGE ADJUST
STATOR COILS
−
TA233566

Figure 13-31. Inductor Alternator.

part of the driving power system or a separate self-contained system.

Some oil-cooled system advantages are that the generator can be sealed completely, preventing entrance of foreign matter; cooling oil can be used for bearing lubrication; the rotor can be solid, reducing windage losses; and generator efficiency can be higher because the effective losses that occur in oil circulation are constant with generator speed.

Several disadvantages encountered with oil cooling include the consideration that complex manifolding, porting, seals, and passages increase costs; and that auxiliary heat exchangers and pumps increase cost, weight, and complexity.

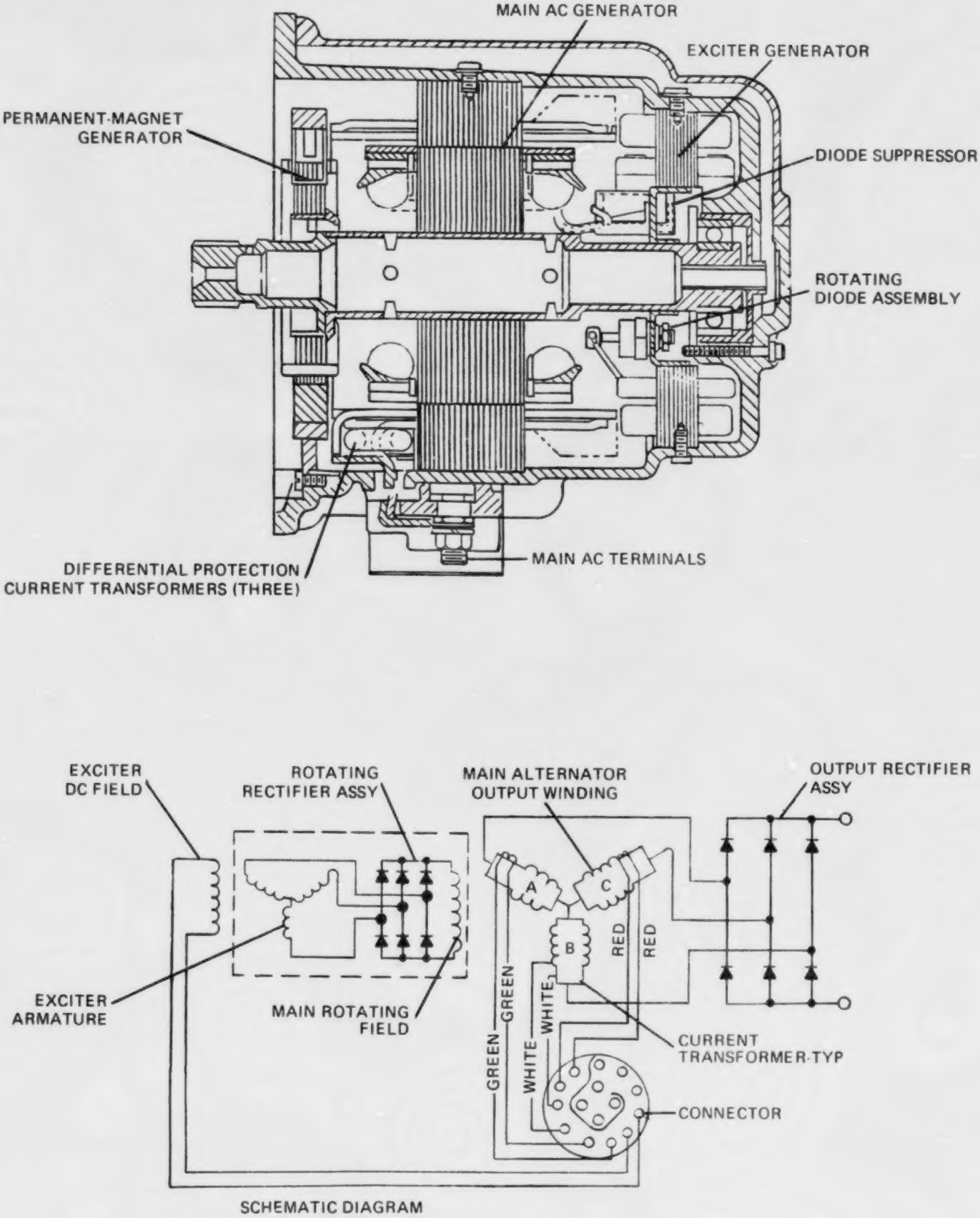
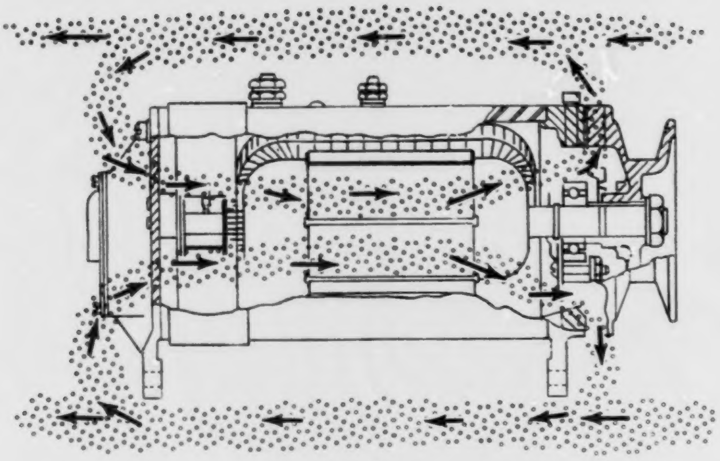

MAIN AC GENERATOR
EXCITER GENERATOR
PERMANENT-MAGNET GENERATOR
DIODE SUPPRESSOR
ROTATING DIODE ASSEMBLY
DIFFERENTIAL PROTECTION CURRENT TRANSFORMERS (THREE)
MAIN AC TERMINALS
EXCITER DC FIELD
ROTATING RECTIFIER ASSY
MAIN ALTERNATOR OUTPUT WINDING
OUTPUT RECTIFIER ASSY
A
B
C
RED
RED
GREEN
GREEN
WHITE
WHITE
EXCITER ARMATURE
MAIN ROTATING FIELD
CURRENT TRANSFORMER-TYP
CONNECTOR
SCHEMATIC DIAGRAM

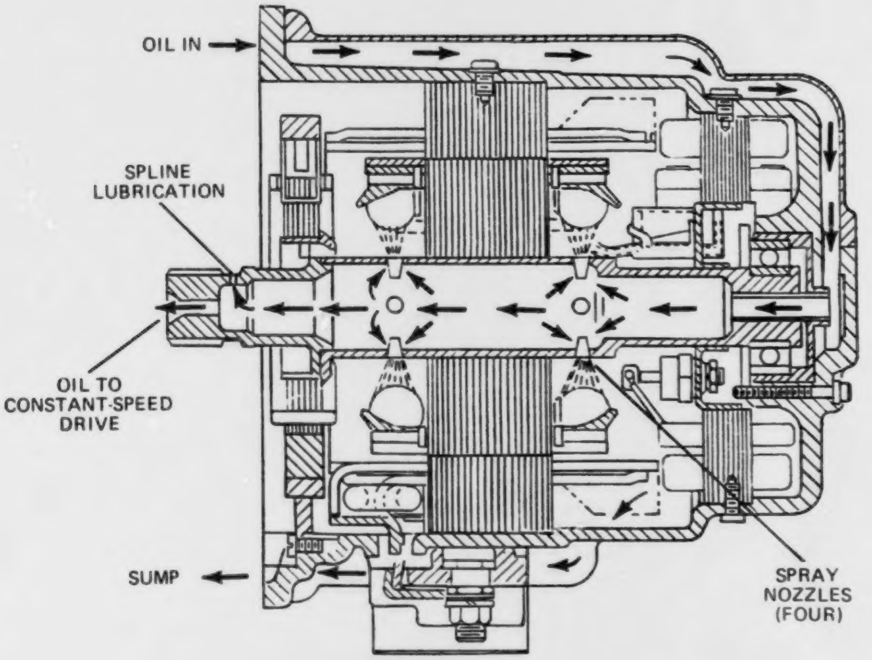
Figure 13-32. Brushless-Rotating Rectifier.

TA233567

293



A. AIR COOLED


OIL IN
SPLINE LUBRICATION
OIL TO CONSTANT-SPEED DRIVE
SUMP
SPRAY NOZZLES (FOUR)

B. OIL COOLED

Figure 13-33. Generator Cooling.

TA233568

13-26. AC Generator Regulation. The regulation of ac generator output, though just as important as the regulation of dc generator output, is much simpler for the following reasons:

a. The ac generator, because of its rectifier bridge, will not allow current to backflow into it during shutdown. This eliminates the need for a cutout relay.

b. An ac generator will limit its current automatically by regulating the voltage. A current regulator, therefore, is not needed in the voltage regulator.

Because a cutout relay and a current regulator are not necessary, an ac generator voltage regulator contains only a voltage regulation element. A typical single-element voltage regulator for an ac generator is shown in figure 13-34. For comparison, a typical three-element voltage regulator for a dc generator is also shown.

13-27. Vibrating Point Regulator.

a. Description (Fig. 13-35). The vibrating point voltage regulator is a single-element unit that limits system voltage. The element consists of a double set of contact points that are operated by a magnetic coil. The center contact is stationary and connected directly to the generator field. The upper and lower contact points are pulled downward by the magnetic coil against the force of a spring. The upper and lower contacts always maintain the same distance from each other. The upper contact is shunted directly to the ground. The lower contact connects to battery voltage as does the operating coil. A resistor is connected from the battery to the field connection.

b. Operation (Fig. 13-35). The lower contact normally is connected to the center contact because of spring tension. As the magnetic coil is energized, the movement of the upper and lower contacts will disconnect the center and lower contacts. As they move further, the upper contact will become connected to the center contact. The following describes the operation:

(1) As the operation begins, the center contact is connected to the lower contact, sending full battery voltage to the field winding. This will cause the alternator to produce full output.

(2) As the alternator raises system voltage, the force exerted by the magnetic coil increases. This causes the upper and lower contacts to move, which in turn breaks the connection between the center and lower contacts. The field then receives reduced voltage from the resistor, causing a corresponding reduction in alternator output. The resulting lower system voltage decreases magnetic coil force, allowing the lower and center points to come together again. This is

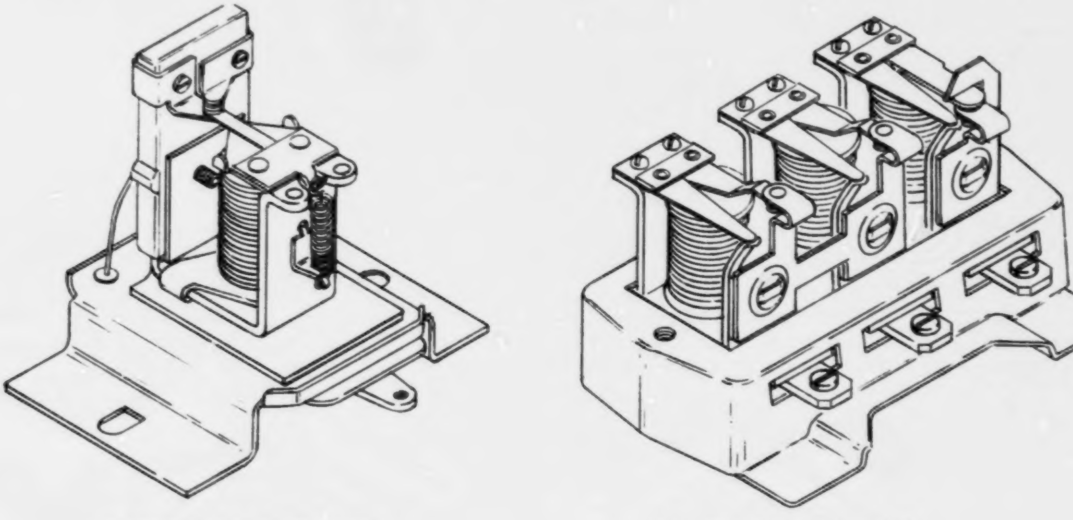


Figure 13-34. AC and DC Regulator Comparison.

TA233569

295

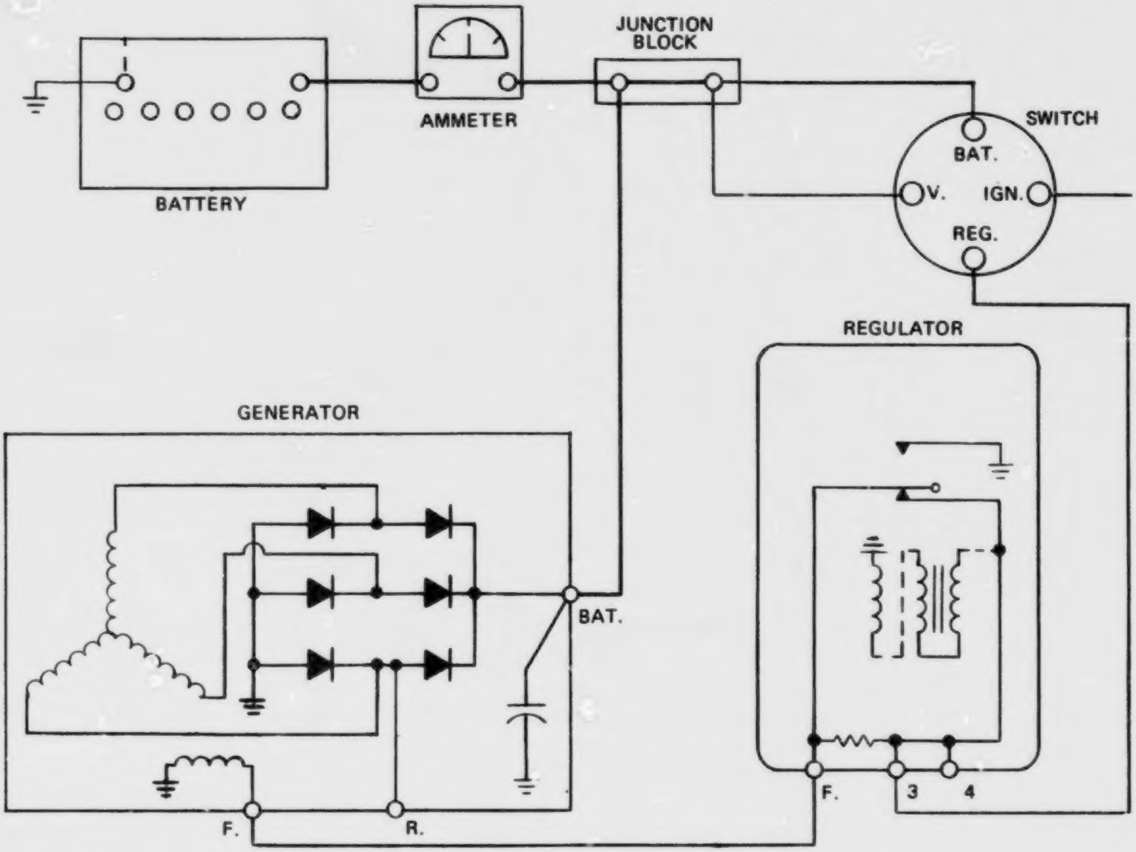


Figure 13-35. Vibrating Point Regulating Circuit.

a constantly repeating cycle (many times a second) that serves to limit electrical system voltage. The magnetic coil force and spring tension are calibrated to maintain the desired voltage, which is usually approximately 13.2 to 13.8 volts in commercial vehicles.

(3) During periods of light electrical loads, particularly at high speeds, the system voltage may go too high even with reduced field voltage from the resistor. When this happens, the magnetic coil will pull the upper contact into connection with the center contact. This will shunt all field current to ground, causing the alternator to stop producing current.

13-28. Transistorized Point Regulator (Fig. 13-36). The operation of the regulator is essentially the same as the vibrating point regulator. The main difference is that the contacts only carry a current that is used to trigger a transistor. Based on this signal current from the points, the transistor will control and carry the field current. The advantage to this configuration is increased contact point life. This is because the signal current to the transistor is low and causes very little arcing.

13-29. Solid-State Voltage Regulator (Fig. 13-37). A solid-state voltage regulator is a static unit that is totally electronic in operation. In this configuration, the contact points are replaced by zener diodes (para 11-7). The zener diodes produce a signal to the base of a transistor whenever the electrical system voltage reaches the desired level. This signal to the base of the transistor reduces or shuts off field current to reduce or stop alternator output. When the system voltage drops again, the transistor again will allow alternator output. This cycle will repeat itself as much as 2000 times per second. Some applications utilize a rheostat to adjust the

TA233570

296

BEST COPY AVAILABLE

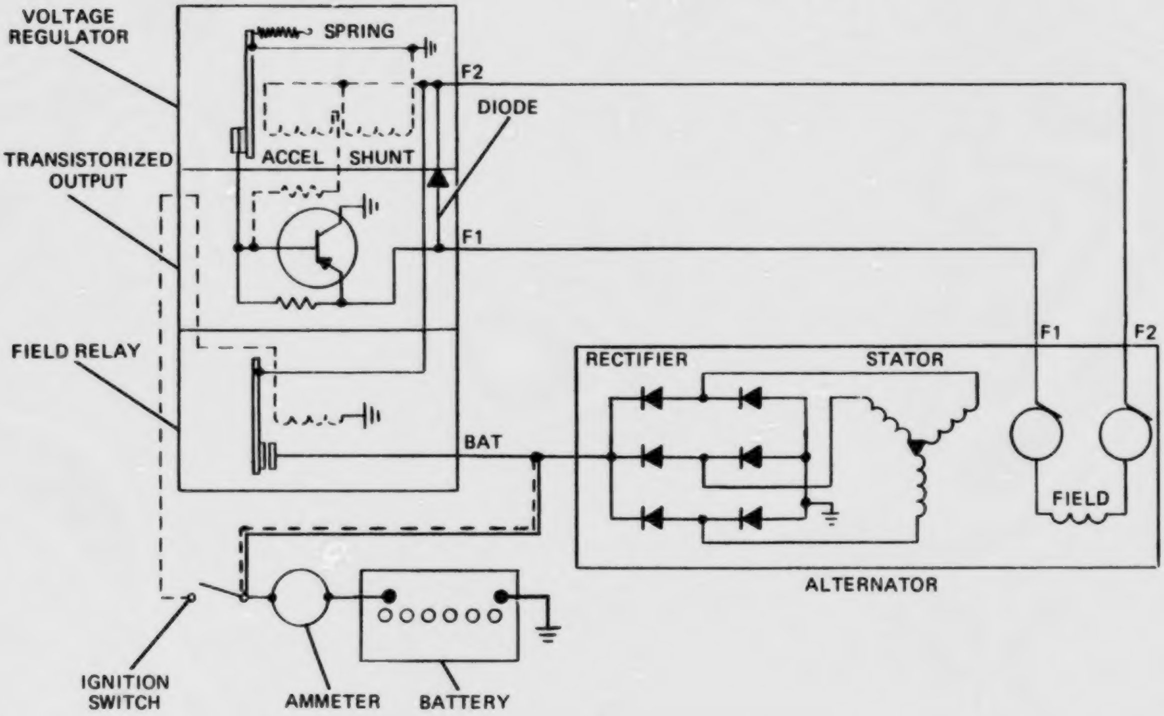


Figure 13-36. Transistorized Voltage Regulator.

resistance of the field current, thereby regulating alternator output. The solid-state regulator virtually has replaced the mechanical units in all currently produced equipment due to the extreme reliability and low manufacturing costs of solid-state components. Another desirable feature of a solid-state regulator is that it can be made small enough to be built into the alternator.

13-30. Accessory Items.

a. Fuel Pressure Field Switch (Fig. 13-38). The fuel pressure field switch is a device that is used on high output alternators to prevent the alternator from placing a load on the engine until it is running by opening the alternator field circuit until the fuel pressure reaches the normal operational range.

b. Field Relay. The field relay is used in two basic applications:

(1) It can be used to isolate the field circuit from the battery whenever the ignition switch is turned off (fig. 13-39). In this application, the magnetic coil is energized with the ignition switch. The contact points then pull together, completing the field circuit.

(2) It also can be used to operate an alternator no-charge warning light (fig. 13-39). In this application, the magnetic coil is energized by one of the stator windings. This will cause the contact points to be pulled together whenever the alternator produces sufficient current to sustain operational voltage. When the contact points are open (alternator not operating), the field circuit receives current from a lead that passes in series through an indicator lamp that is in parallel with a resistor. The field current will cause the lamp to light. As the alternator begins to produce, the field relay contact points will close, shunting the field circuit directly to battery voltage, causing the indicator lamp to go out.

TA233571

297

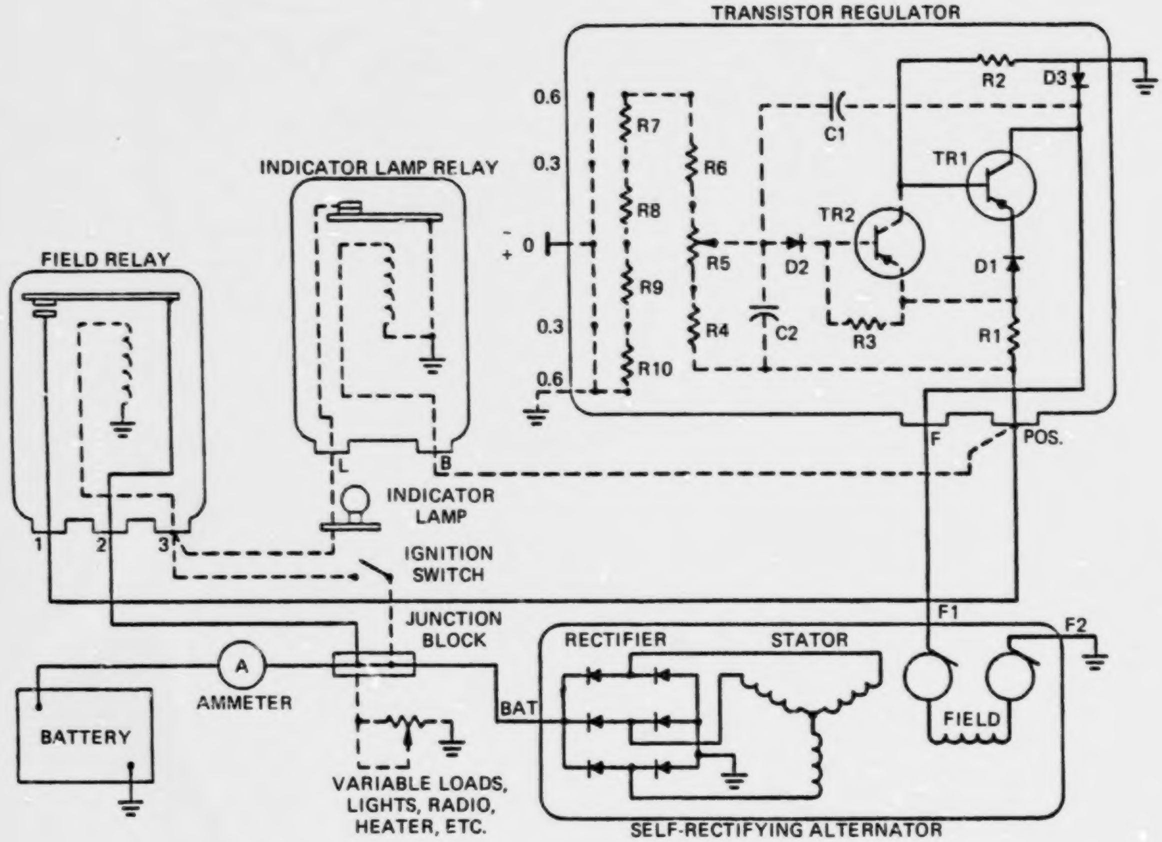

TRANSISTOR REGULATOR
0.6
0.3
- 0 +
0.3
0.6
R7
R6
R8
R5
R9
R4
R10
C1
C2
D2
R3
TR2
TR1
R2
D3
D1
R1
F
POS.
INDICATOR LAMP RELAY
L
B
FIELD RELAY
1
2
3
INDICATOR LAMP
IGNITION SWITCH
JUNCTION BLOCK
A
AMMETER
BATTERY
VARIABLE LOADS, LIGHTS, RADIO, HEATER, ETC.
BAT
RECTIFIER
STATOR
F1
F2
FIELD
SELF-RECTIFYING ALTERNATOR

Figure 13-37. Solid-State Regulator Circuit.

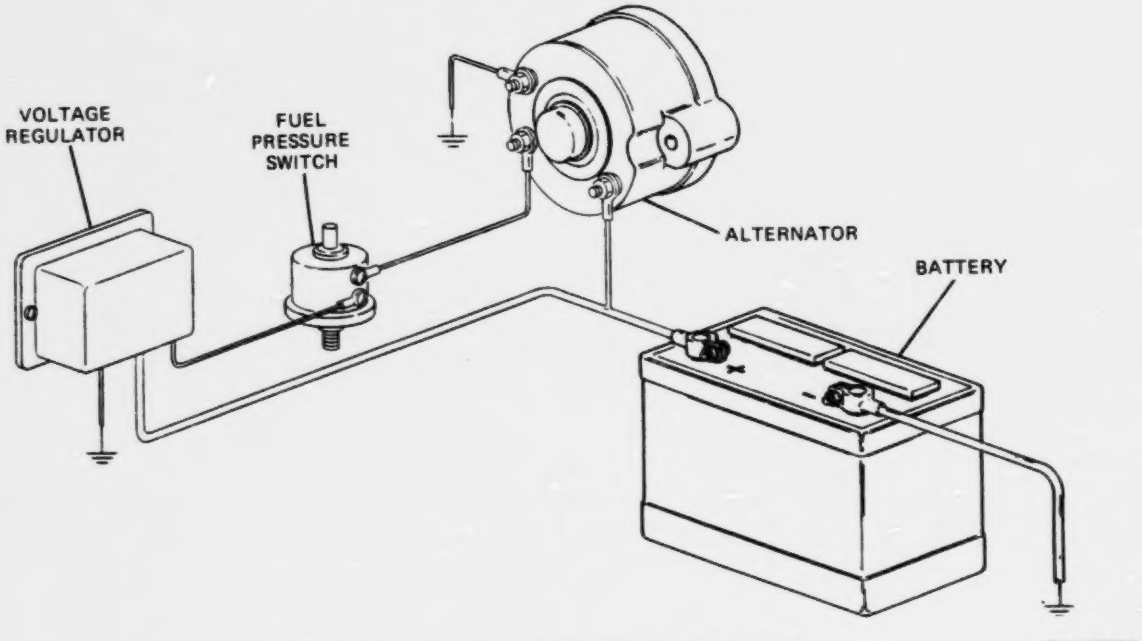

VOLTAGE REGULATOR
FUEL PRESSURE SWITCH
ALTERNATOR
BATTERY
+
-
TA233572

Figure 13-38. Fuel Pressure Field Switch Circuit.

298

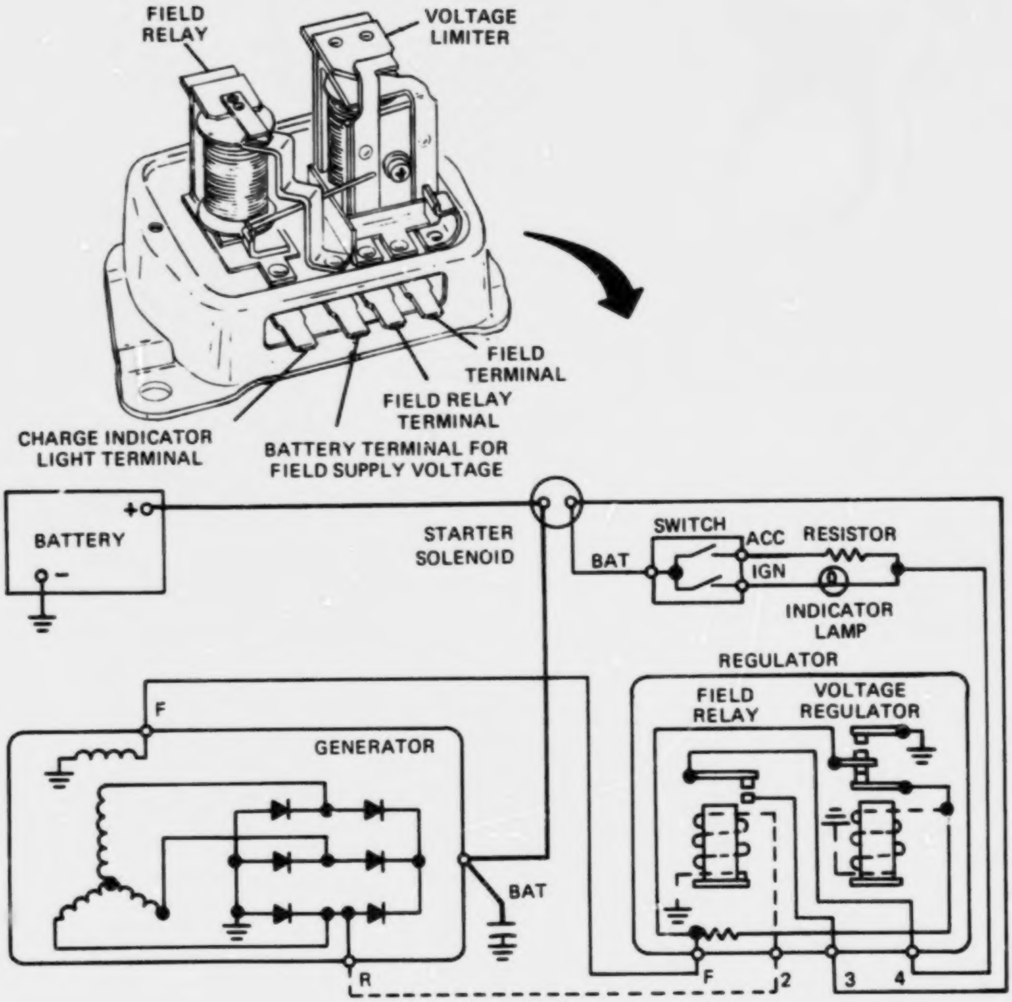

FIELD RELAY
VOLTAGE LIMITER
FIELD TERMINAL
FIELD RELAY TERMINAL
CHARGE INDICATOR LIGHT TERMINAL
BATTERY TERMINAL FOR FIELD SUPPLY VOLTAGE
BATTERY
+
-
STARTER SOLENOID
SWITCH
BAT
ACC
IGN
RESISTOR
INDICATOR LAMP
REGULATOR
FIELD RELAY
VOLTAGE REGULATOR
F
GENERATOR
BAT
R
F
2
3
4

Figure 13-39. Field Relay and Warning Light Circuit.

TA233573

CHAPTER 14

STARTING SYSTEMS

Section I. ELECTRIC STARTING MOTOR

14-1. General. Any internal combustion engine must be cranked manually to start it running on its own. Early automotive vehicles were started by the driver through the use of a handcrank. A system of cranking the engine with an electric motor was developed as automotive technology progressed. The modern electric starting system has reduced the task of starting an internal combustion engine to the turn of a key or the pushing of a button.

14-2. Simple DC Motor.

a. Construction. An electric motor is constructed essentially the same as a generator. If the brushes of the simple generator are connected to a battery and current is permitted to flow through the loop of wire (1, fig. 14-1), the loop of wire will rotate in the direction indicated by the arrow. This rotation is due to the repulsion between the field magnetism and the magnetic whirl set up around the loop of wire by the current (2, fig. 14-1).

b. Operation. The repulsion is caused by all the magnetic lines of force tending to flow around the conductor in the same direction. This distorts and crowds the magnetic lines on one side of the conductor more than on the other, which results in a repulsion of the conductor (3, fig. 14-1). In other words, the rubberband characteristic of the lines of force (that is, when they try to shorten to a minimum length) causes the lines to exert a push on the conductor. If the magnetic field is reversed, with the direction of current unchanged, the magnetic lines of force will crowd to the other side of the conductor, and it will be repelled in the opposite direction (4, fig. 14-1). The same action would result if the current, instead of the magnetism, were reversed. Thus, in figure 14-1, owing to the current flowing in reverse directions

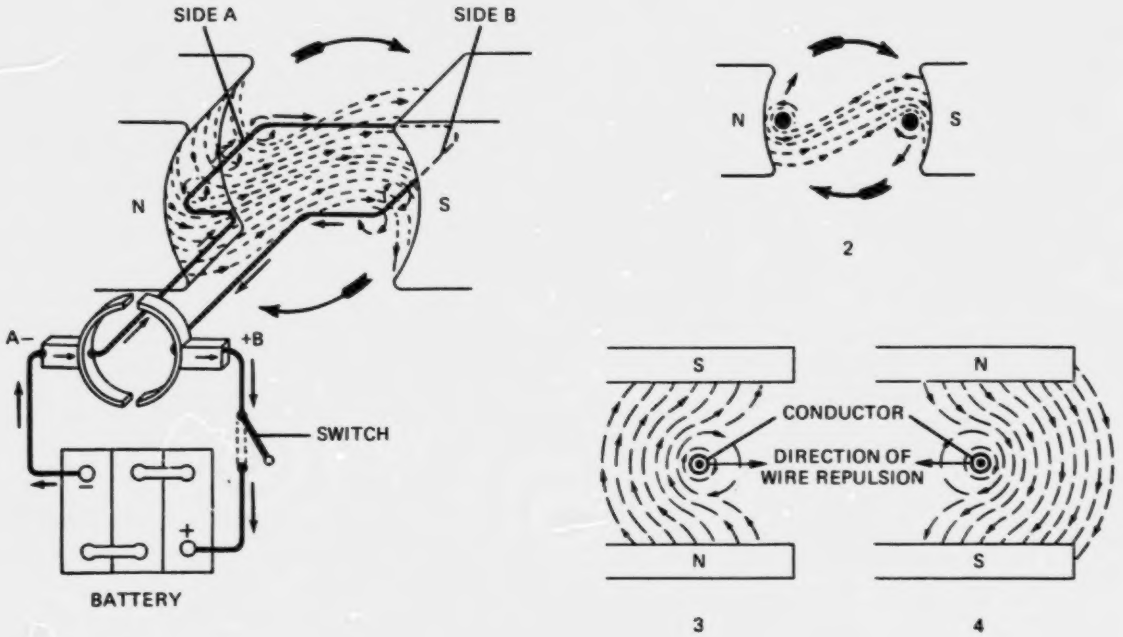


Figure 14-1. Simple DC Motor.

TA233574

in the two sides A and B of the loop, and the consequent field distortion (2, fig. 14-1), A will be repulsed upward and B downward, and the loop will rotate in a clockwise direction.

14-3. Automotive Starting Motor.

a. General (Fig. 14-2). In use, the motor armature has many armature coils equally spaced around the entire circumference of the armature. Each of these coils carries current and consequently exerts a force to rotate the armature as it passes the pole pieces. The switching of the armature coils to the brushes is handled by a segmented commutation. The result is a comparatively high turning power (or torque) that is sufficient to crank the engine if it is applied through suitable gear reductions.

b. Construction. A cutaway view of a typical automotive starter is shown in figure 14-3. The basic motor consists of the following parts.

(1) *Armature.* The armature contains multiple loops of heavy copper. These coils pass through a laminated core of iron to increase the permeability of the armature. The commutator segments are made of heavy copper bars that are set into mica or epoxy resins. The armature rotates on bronze bushings.

(2) *Field Coils.* The field coils electromagnetically create the magnetic field that cause armature rotation. They are constructed of heavy copper wire that is usually rectangular in cross section. An insulating material is placed within the windings to insulate the coils from each other. The coils then are insulated on the outside by either wrapping them in paper or sealing them in rubber. The field coils are secured to the field frame by the pole shoes. The pole shoes serve as a core for the field coils to increase permeability.

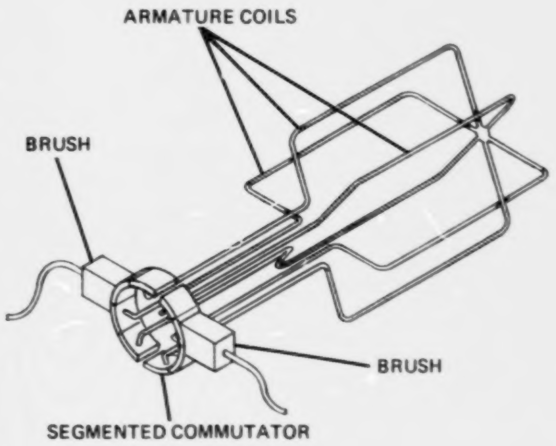


Figure 14-2. Automotive Starting Motor.

c. Field Circuit Configurations. Field circuits will vary according to the application of the starter. The following are the most popular.

(1) *Two Windings: Parallel (A, fig. 14-4).* The wiring of two field coils in parallel will increase their field strength because they each receive full voltage. Note that two additional pole shoes are used. Though they have no windings, their presence will strengthen further the magnetic field.

(2) *Four Windings: Series-Parallel (B, Fig. 14-4).* The wiring of four field coils in a series-parallel combination will create a much stronger magnetic field than the two field coil configuration described above.

(3) *Four Windings: Series (C, Fig. 14-4).* The wiring of four field coils in series will provide a large amount of low-speed starting torque, which is a very necessary characteristic of an automotive starting motor. An undesirable characteristic of series-wound motors is that they will build up excessive speed if allowed to run free to the point where they will destroy themselves.

(4) *Six Windings: Series-Parallel (D, Fig. 14-4).* Three pairs of series-wound field windings provide the magnetic field for a heavy-duty starter. This configuration uses six brushes.

(5) *Three Windings: Two Series, One Shunt (E, Fig. 14-4).* The use of one field coil that is shunted to ground with a series-wound motor will control motor speed. The shunt coil, because it is not affected by speed, will draw a steady, heavy current, effectively limiting speed.

14-4. Starter Motor Drives.

a. General (Fig. 14-5). The starter may drive the engine through a pinion or by a dog clutch attached to the starter armature shaft. The shaft is

TA233575

301

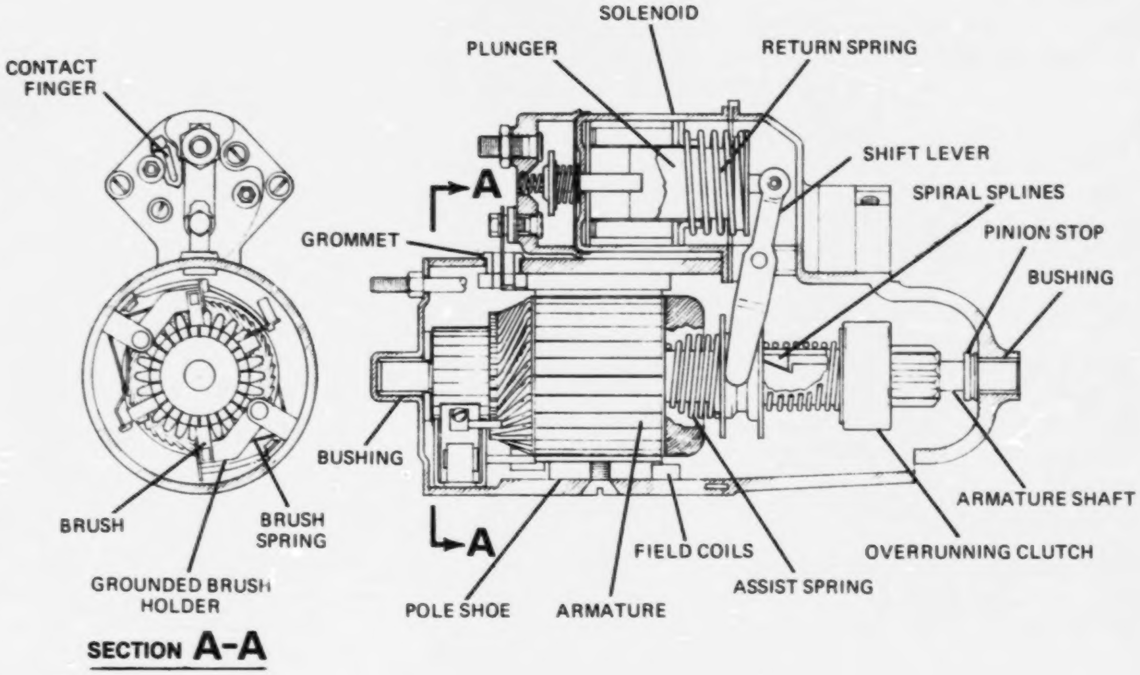

SOLENOID
PLUNGER
RETURN SPRING
CONTACT FINGER
SHIFT LEVER
A
SPIRAL SPLINES
PINION STOP
GROMMET
BUSHING
BUSHING
ARMATURE SHAFT
BRUSH
BRUSH SPRING
A
FIELD COILS
OVERRUNNING CLUTCH
GROUNDED BRUSH HOLDER
ASSIST SPRING
POLE SHOE
ARMATURE
SECTION A-A

Figure 14-3. Typical Starting Motor.

brought together with the teeth cut on the rim of the flywheel or with the mating half of the dog clutch. The drive must be equipped with an overrunning clutch or some other means of quick disengagement. Owing to limitations of size and capacity of the battery, a high-speed starter with a high gear reduction is used to obtain the necessary torque. The great speed reduction required is affected in the majority of cases by utilizing the flywheel as a driven gear. In some instances, the gear is bolted or shrunk on the flywheel, while in others the gear teeth are cut directly in the rim of the flywheel itself. The starter is mounted on the flywheel housing.

b. Gear Reduction Starters (Fig. 14-6). The gear reduction obtained through the flywheel gear with a single reduction is usually approximately 11:1 or 12:1 (sometimes it is as high as 16:1); that is, the speed of the starter armature is 11 or 12 times that of the flywheel. The pinion gear on the armature shaft meshes directly with the gear teeth on the flywheel. In some instances, however, a double reduction is used, in which case the gear ratio may be as high as 25:1 or even 40:1. With double reduction, the gear on the armature shaft does not mesh directly with the teeth on the flywheel but with an intermediate gear, which drives the flywheel driving pinion. The double-reduction drive permits the use of a very small starter running at high speed, but it has the disadvantage of requiring a more complicated mechanism than the single-reduction drive.

c. Overrunning Clutch (Fig. 14-7). Power can be transmitted through the overrunning clutch in one direction only, which prevents the engine from driving the starter. The shell and sleeve assembly of the clutch is driven by the starter armature shaft. The inner portion, or rotor, is connected to the pinion, which meshes with the teeth on the engine flywheel. Steel rollers are located in wedge-shaped spaces between the rotor and the shell. Springs and plungers normally hold the rollers in position within the wedge spaces. When the starter armature shaft turns, the rollers are jammed between the wedge-shaped surfaces, causing both the inner and the

TA233576

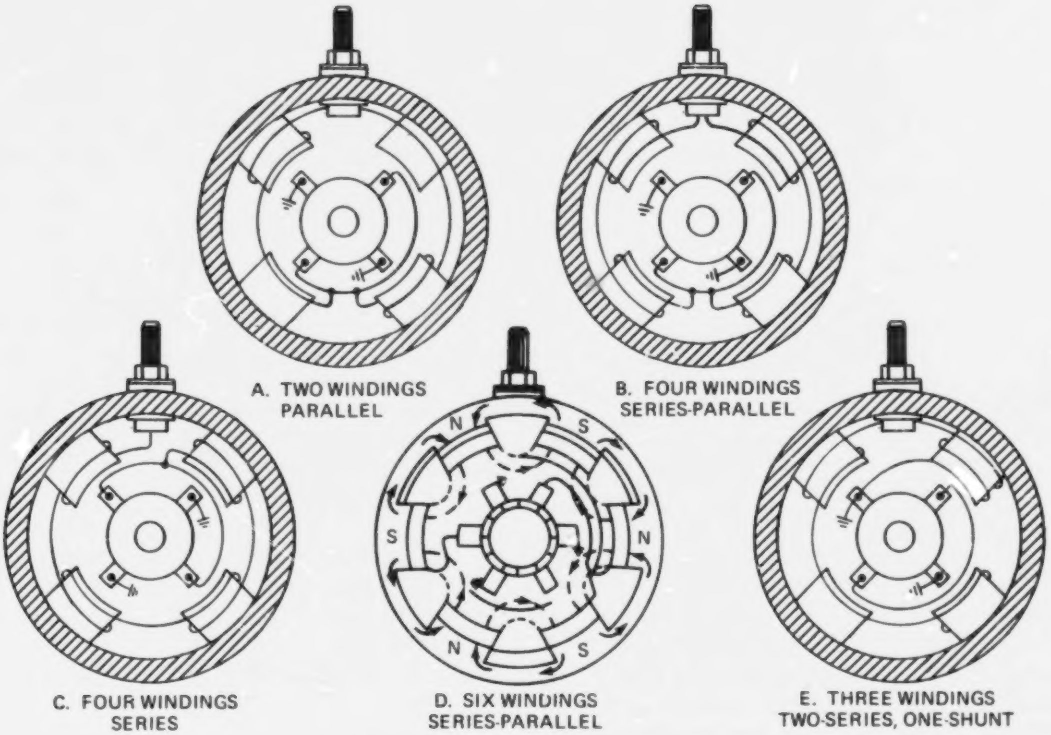

A. TWO WINDINGS PARALLEL
B. FOUR WINDINGS SERIES-PARALLEL
C. FOUR WINDINGS SERIES
D. SIX WINDINGS SERIES-PARALLEL
E. THREE WINDINGS TWO-SERIES, ONE-SHUNT
N
S
S
N
N
S

Figure 14-4. Field Winding Configurations.

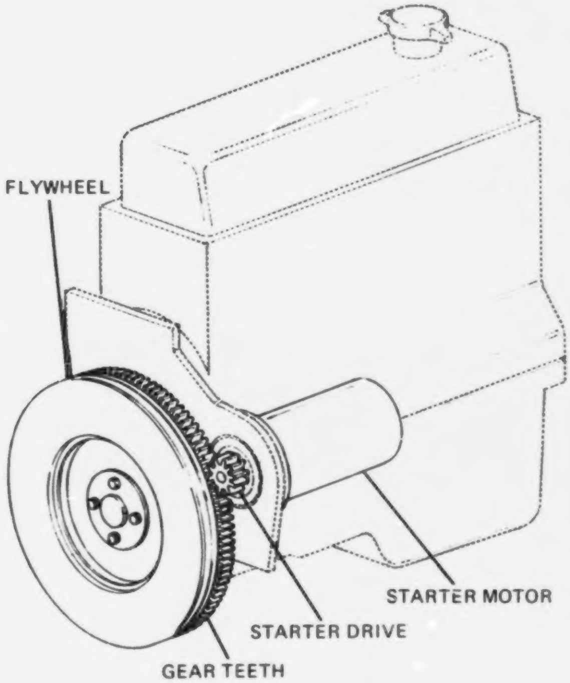

FLYWHEEL
STARTER MOTOR
STARTER DRIVE
GEAR TEETH

Figure 14-5. Starter Drives.

TA233577

303

BEST COPY AVAILABLE

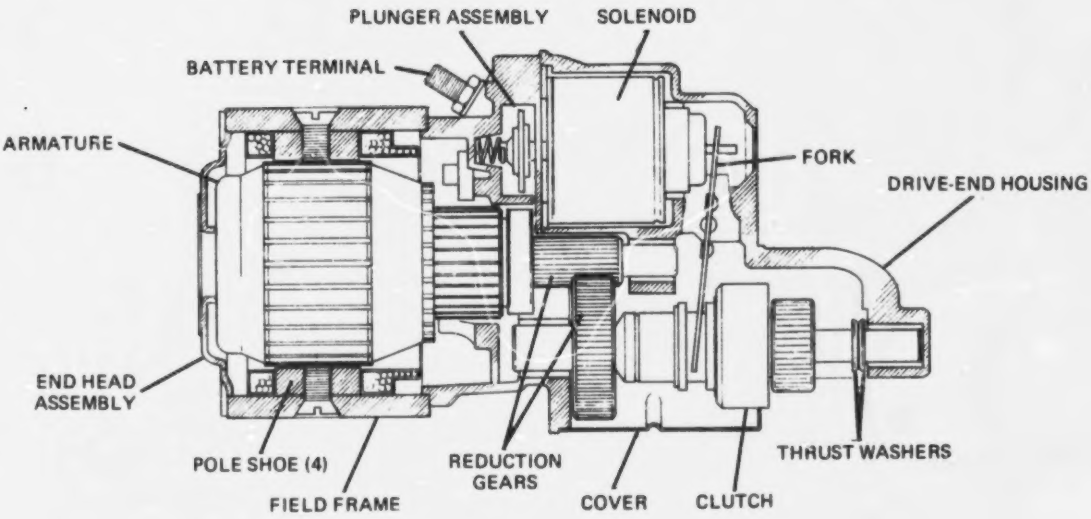

PLUNGER ASSEMBLY
SOLENOID
BATTERY TERMINAL
ARMATURE
FORK
DRIVE-END HOUSING
END HEAD ASSEMBLY
THRUST WASHERS
POLE SHOE (4)
REDUCTION GEARS
FIELD FRAME
COVER
CLUTCH

Figure 14-6. Gear Reduction Starter.

outer members to rotate as a unit and crank the engine. As soon as the engine transmits power through the pinion in a reverse direction, the pinion and rotor assembly is driven by the flywheel. This action tends to work the rollers back against the plungers to where the space is greater, causing a slipping or overrunning action. As a result, the clutch cannot be driven in this direction. This prevents excessive speeds of the starter.

d. Pedal Shift (Fig. 14-8). With this type of starting mechanism, the starter pinion is meshed when the driver presses the starter pedal. When the yoke lever is moved by the action of the driver in stepping on the starter pedal, the pinion gear is shifted into mesh with the flywheel gear. After the gears are in mesh, continued movement of the pedal operates the starter switch and causes the starter to crank the engine. In case the pinion does not mesh perfectly with the flywheel, further motion of the shift lever compresses a spring so that the pinion will snap into place the instant the starter armature begins to rotate. After the engine has started, releasing the starter pedal will pull the pinion out of the mesh.

e. Solenoid Shift (Fig. 14-9). Shifting the overrunning clutch pinion gear in mesh with the flywheel gear is made automatic on a good proportion of modern vehicles by the use of a solenoid.

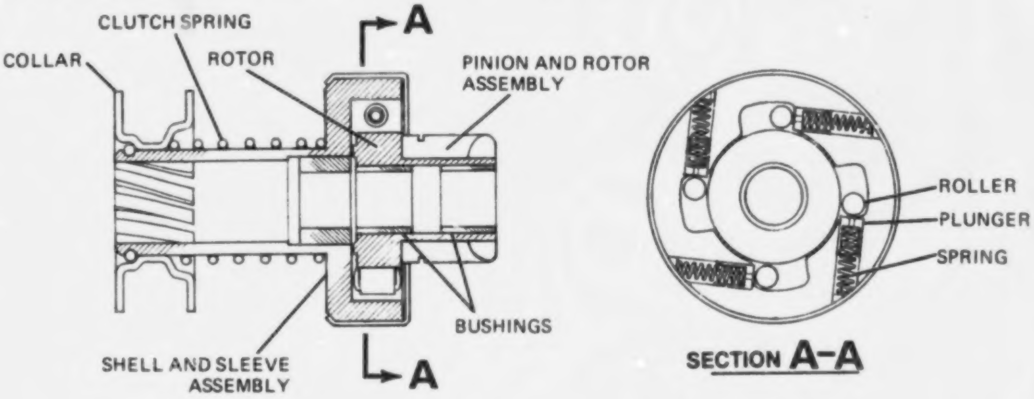

CLUTCH SPRING
A
COLLAR
ROTOR
PINION AND ROTOR ASSEMBLY
ROLLER
PLUNGER
SPRING
BUSHINGS
SHELL AND SLEEVE ASSEMBLY
A
SECTION A–A

Figure 14-7. Overrunning Clutch.

TA233578

304

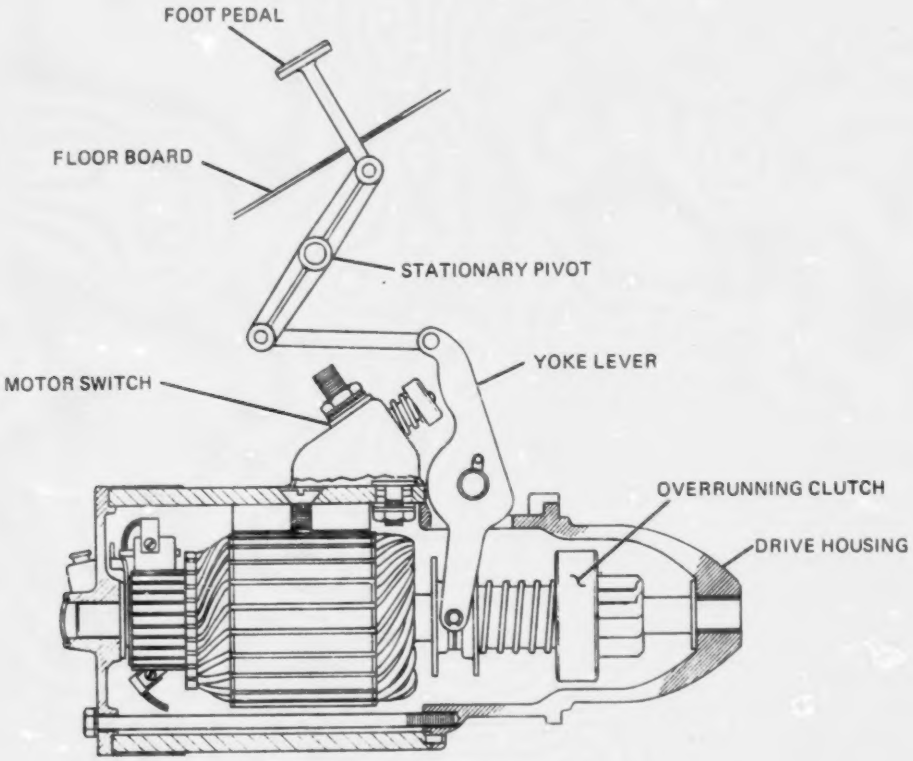


Figure 14-8. Pedal Shift Starter.

(1) *Definition of Solenoid.* A solenoid is a coil of wire wound in a spiral of one or more layers, which produces a magnetic field when current is passed through it. The magnetic field thus produced flows in concentric circles around the wire.

(2) *Operation of Solenoid Shift.* A remote control switch is necessary to operate the solenoid. The ignition switch is connected to the control circuit so that the starter will not operate until the ignition is on. The solenoid shift unit is mounted rigidly on the starter field frame. Inside the solenoid coil is a heavy plunger connected to the shift lever. The two larger terminal posts on the shift unit are connected in series with the starter. The smaller terminal that leads to the solenoid is connected to the remote control circuit. When the remote control circuit is closed to supply current to the solenoid coil, the solenoid exerts a pull on the shift plunger, which shifts the pinion to engage with the flywheel teeth. After the pinion shift lever has moved the distance required for engaging the pinion gear, the pointed end of the shift plunger presses against the end of a contact plunger. This action pushes a contact disk on the contact plunger across the switch contacts to operate the starter. An overrunning clutch is required with this system to prevent damage to the starter at the time the engine starts.

f. Bendix Starter Drive (Fig. 14-10). The Bendix drive is a starting mechanism that seldom is used on modern vehicles. This automatic screw pinion shift mechanism is built in two distinct styles: the inboard type, in which the pinion shifts toward the starter to engage the flywheel, and the outboard type, in which the pinion shifts away from the starter. The same general construction is used in both types. A sleeve having screw threads (usually a triple thread), with stops at each end to limit the lengthwise travel of the pinion, is mounted on the extended armature shaft. The pinion gear, which is unbalanced by a weight on one side, has corresponding internal threads for mounting on this sleeve. The sleeve is connected to the starter armature shaft through a special drive spring attached to a collar pinned to the armature shaft.

TA233579

305

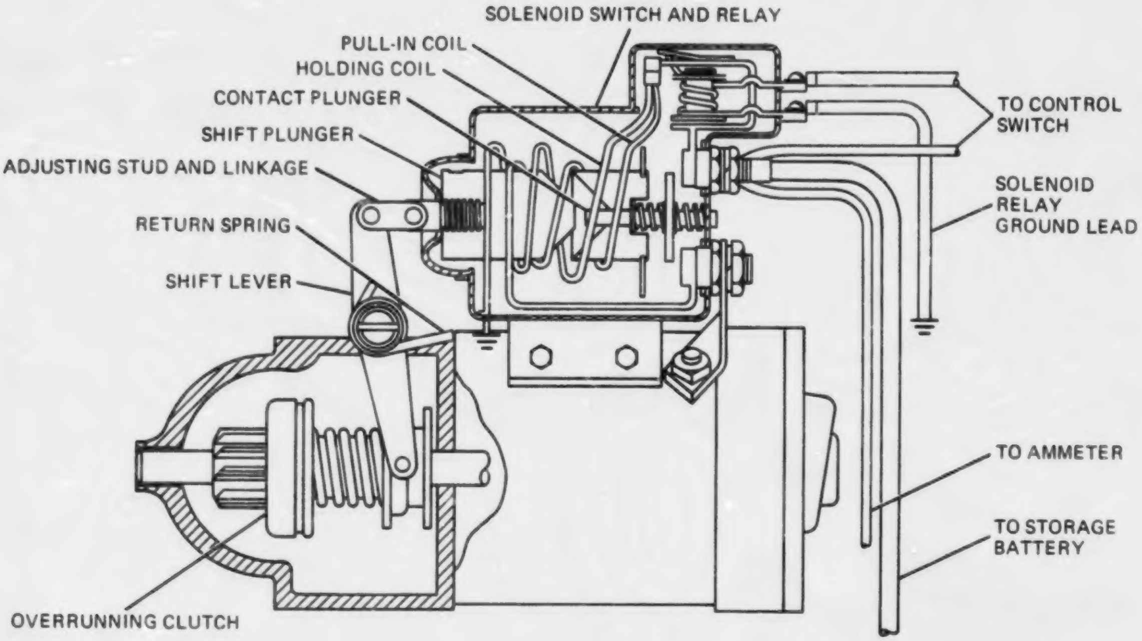


Figure 14-9. Solenoid Shift Starter.

(1) *Operation.* When the starter is not operating, the pinion is out of mesh and entirely away from the flywheel gear. When the starter switch, which may be foot or hand operated, is closed and the total available battery voltage is impressed on the starter, the armature immediately starts to rotate at high speed. The pinion, being weighted on one side and having internal screw threads, does not rotate immediately with the shaft but, because of its inertia, runs forward on the revolving threaded sleeve until it meets or engages with the flywheel gear. If the teeth of the pinion and the flywheel meet instead of engaging, the drive spring allows the pinion to revolve and forces it into mesh with the flywheel. When the pinion gear is engaged fully with the flywheel gear, the pinion then is driven by the starter through the compressed drive spring and cranks the engine. The drive spring acts as a cushion while the engine is being cranked against compression. It also breaks the severity of the shock on the teeth when the gears engage and when the engine kicks back due to ignition. When the engine fires and runs on its own power, the flywheel drives the pinion at a higher speed than does the starter, causing the pinion to turn in the opposite direction on the threaded sleeve and automatically disengages from the flywheel. This prevents the engine from driving the starter. When the pinion is disengaged from the flywheel automatically, it is held in this position by a latch until the starter switch is closed again.

(2) *Advantages.* The chief advantages claimed for this type of starter are listed below.

(a) It is simple in construction.

(b) The mechanism is automatic in operation, requiring no action by the operator other than pressing the starter switch.

(c) It gives high starting speed, because the starter is permitted to pick up speed before the load is applied.

(d) The engine is given a high cranking torque immediately, thus requiring little cranking and minimizing the demand on the battery.

(3) *Disadvantages.* The chief disadvantages are listed below.

(a) The quick impulse given to the pinion is likely to cause nicking or breaking of the teeth

TA233580

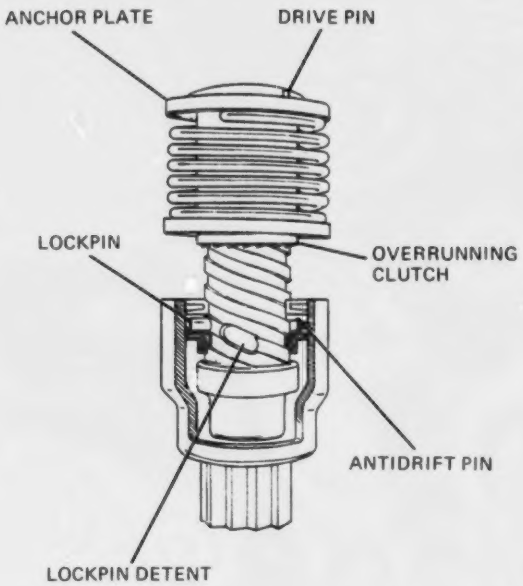


Figure 14-10. Bendix Starter Drive.

when the pinion does not mesh properly on first contact with the flywheel teeth.

(b) Breakage or nonfunctioning of the pinion latch will cause the pinion to drift toward the flywheel teeth, which is likely to cause damage if the engine is running.

c) All of the starter torque is transmitted through the drive spring, which puts it under considerable strain.

Section II. CONTROL SYSTEMS

14-5. Key and Pushbutton Switch Control Circuits (Fig. 14-11). One method of controlling the solenoid shift is by a pushbutton on the instrument panel. Pushing the button closes the control circuit so that current can be supplied to the solenoid coil. Current practice, however, is to eliminate a separate pushbutton switch by incorporating a start position into the key switch. A relay frequently is used in the control circuit to supply current to the solenoid coils. Only a low-current control circuit to the instrument panel pushbutton is then necessary. The relay will close the circuit through the solenoid coil, which carries a larger current.

14-6. Vacuum Lockout Switch Control Circuit (Fig. 14-12). The vacuum lockout switch is incorporated on some vehicles to prevent the starter from accidentally being engaged after the engine is running. The switch has a diaphragm that is actuated by manifold vacuum after the engine starts. The movement of the diaphragm opens the switch, disabling the starter solenoid circuit.

14-7. Generator Lockout Relay (Fig. 14-13). A generator lockout relay sometimes is used to prevent the starter from accidentally being engaged on a running engine. The relay is actuated by the stator terminal on the alternator to open the starter solenoid circuit as the engine runs and the alternator begins producing current.

14-8. Oil Pressure Lockout Circuit (Fig. 14-14). The oil pressure lockout circuit is used on some models to prevent accidental starter engagement to a running engine. As the engine starts, the lockout switch is turned on by the engine oil pressure. The lockout switch will, in turn, actuate a relay that opens the starter solenoid circuit.

TA233581

307

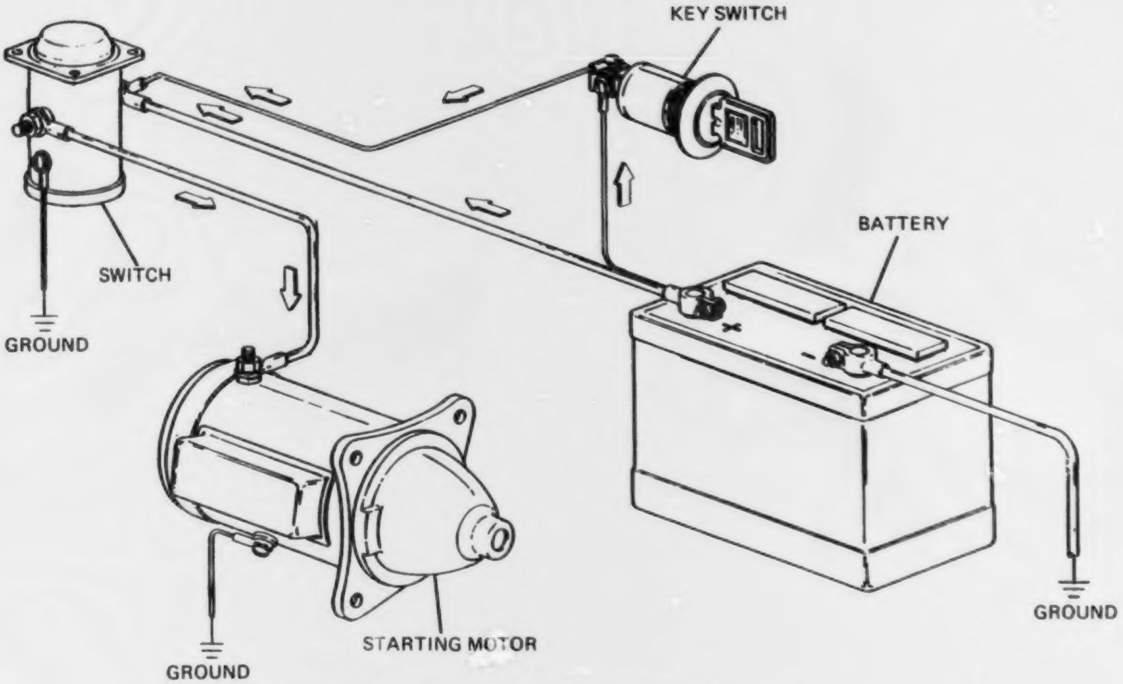

KEY SWITCH
BATTERY
SWITCH
GROUND
GROUND
STARTING MOTOR
GROUND

Figure 14-11. Key and Pushbutton Control Circuits.

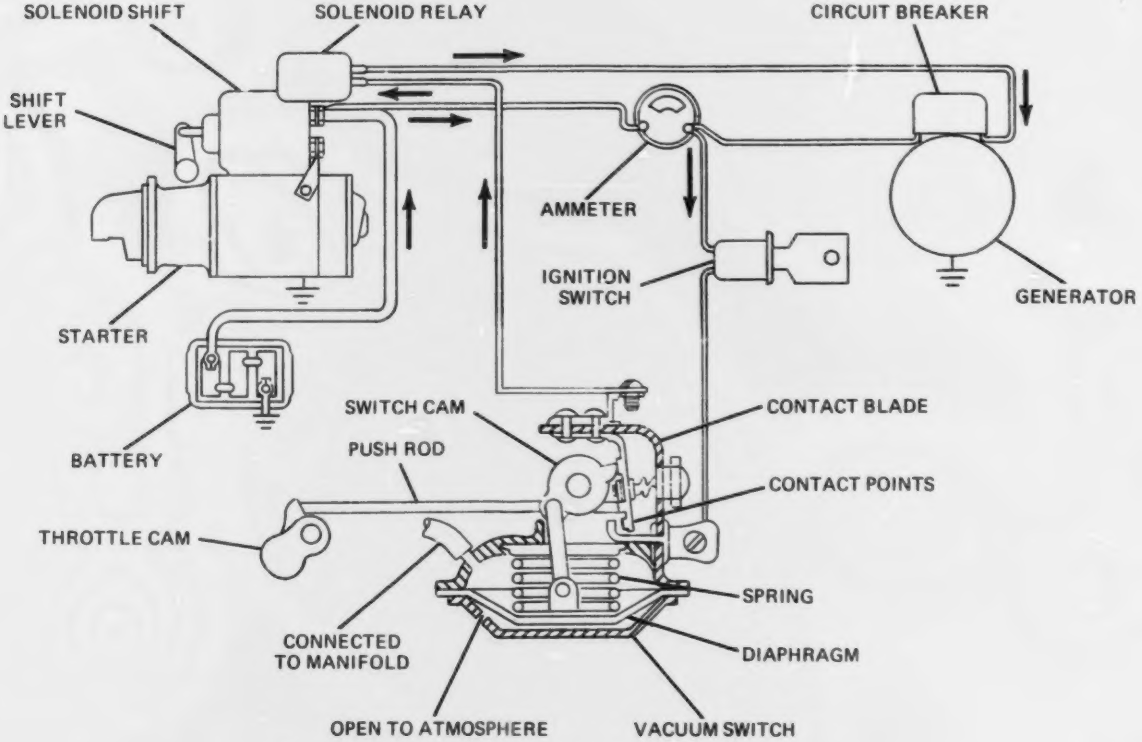

SOLENOID SHIFT
SOLENOID RELAY
CIRCUIT BREAKER
SHIFT LEVER
AMMETER
IGNITION SWITCH
GENERATOR
STARTER
SWITCH CAM
CONTACT BLADE
BATTERY
PUSH ROD
CONTACT POINTS
THROTTLE CAM
SPRING
CONNECTED TO MANIFOLD
DIAPHRAGM
OPEN TO ATMOSPHERE
VACUUM SWITCH

Figure 14-12. Vacuum Lockout Switch Control Circuit.

TA233582

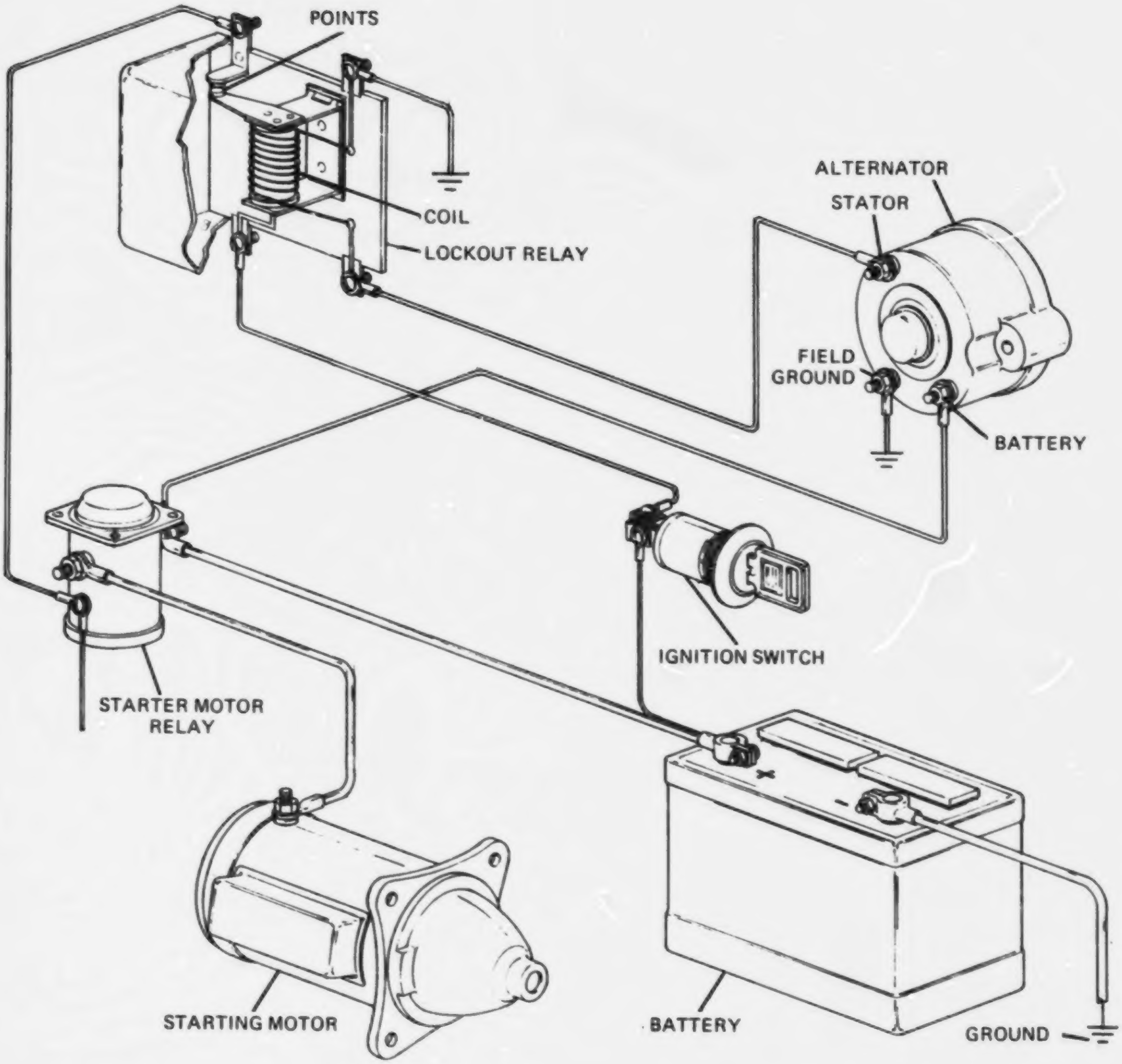

POINTS
ALTERNATOR
STATOR
COIL
LOCKOUT RELAY
FIELD GROUND
BATTERY
IGNITION SWITCH
STARTER MOTOR RELAY
STARTING MOTOR
BATTERY
GROUND

Figure 14-13. Generator Lockout Relay.

TA233583

309

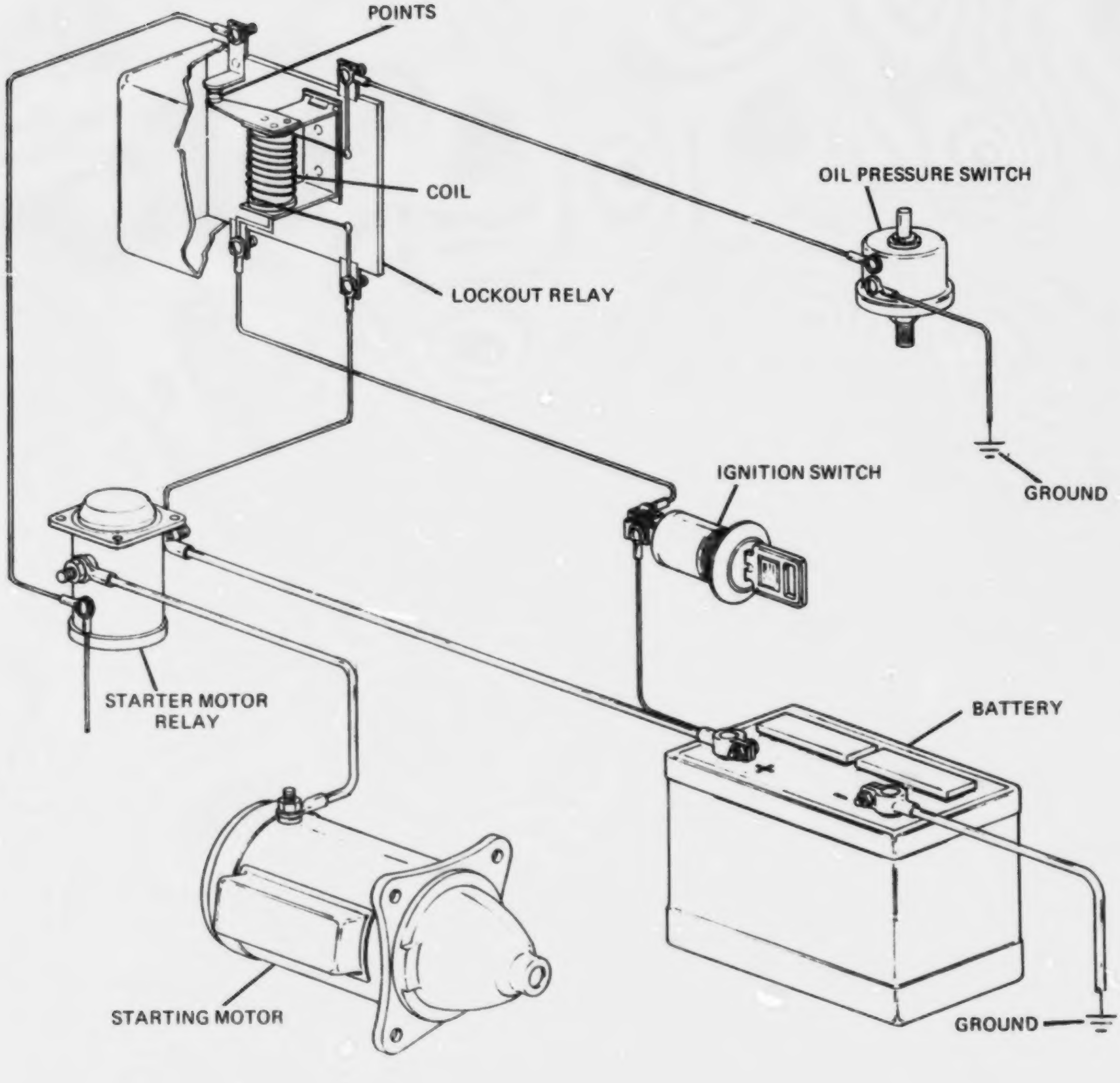

POINTS
COIL
LOCKOUT RELAY
OIL PRESSURE SWITCH
GROUND
IGNITION SWITCH
STARTER MOTOR RELAY
BATTERY
STARTING MOTOR
GROUND

Figure 14-14. Oil Pressure Lockout Circuit.

TA233584

310

CHAPTER 15

IGNITION SYSTEMS

Section I. BATTERY IGNITION SYSTEMS

15-1. Function. Ignition of the fuel-air mixture in the engine cylinder may be accomplished by either of two methods: heat of compression, as in diesel engines; or electric spark, as in gasoline engines. Spark ignition may be subdivided into two classes: battery and magneto. These two systems are essentially the same. With either, the fundamental job is to step up low voltage to a much higher value, and to deliver the high voltage to the spark plugs with the proper timing. The high voltage is capable of pushing current through the high resistance set up by the pressure in the combustion chamber and across from one spark plug electrode to the other. The hot spark created ignites the fuel-air mixture. This section pertains to battery ignition, its theory and operation. Paragraphs 15-9 thru 15-15 describe magneto ignition.

15-2. Operating Principles.

a. Self-Induction (Fig. 15-1).

(1) The principle of electromagnetic induction has been described in paragraph 11-15. When a wire is moved through a magnetic field, or a magnetic field is moved past a wire, the wire will have current induced in it. The magnetic field can be moved past the wire mechanically, or it can be made to move (if it is from an electromagnet) by turning the current on and off. This action causes the magnetic field to build up and collapse. Any wire held in this magnetic field will have current induced in it.

(2) The turns of wire in the electromagnet itself will have current induced in them by the moving magnetic field. For example, figure 15-1 shows two loops, or turns, of an electromagnet. When current first starts to flow, it enters the first loop and a magnetic field begins to build up along with the increase of current. The magnetic field consists of circular lines of force surrounding the wire, and the lines of force move outward and cut through the adjacent loops. These lines of force produce a current in the adjacent loops as they cut through. It is important to note that the induced currents oppose the original currents. This can be determined by use of the left-handed rule, imagining the expanding lines of force from the first loop cutting across the second loop. Note that the lines of force cut across the second loop in a direction that will induce an opposing current.

(3) It would be more correct to say that an opposing voltage is induced. The voltage must come first, then the current. That is, there first must be an electron concentration and an electron shortage in a circuit for current (or electrons) to flow. With this electron imbalance (or this voltage) in existence, there will be an electric current. The opposing or countervoltage that is self-induced by the expanding lines of force is opposite in direction to the voltage from the external source that is forcing current through the loops of the electromagnet.

(4) The effect of the countervoltage is to prevent an immediate magnetic buildup. That is, the countervoltage slows down the rate at which the current flow can increase and the magnetic field can expand and strengthen. The increase of the magnetic field produces the countervoltage; this countervoltage opposes further increases of current flow. However, the external voltage is stronger and therefore continues to increase the strength of the current until it reaches the value determined by the resistance of the circuit, including the electromagnet.

(5) Actually, in most electromagnets, the countervoltage effect slows buildup time only a very small fraction of a second. But with electromagnets of many hundreds or thousands of turns, it does take time for buildup to occur. In the ignition system, if buildup time took too long, the high-voltage sparks would not be produced fast enough and high engine speed could not be attained. However, the ignition coil can function with adequate speed for normal ignition even at high speed.

(6) Not only does the countervoltage appear during buildup, it also occurs during magnetic collapse. That is, when the electromagnet is disconnected from the voltage source so that

311

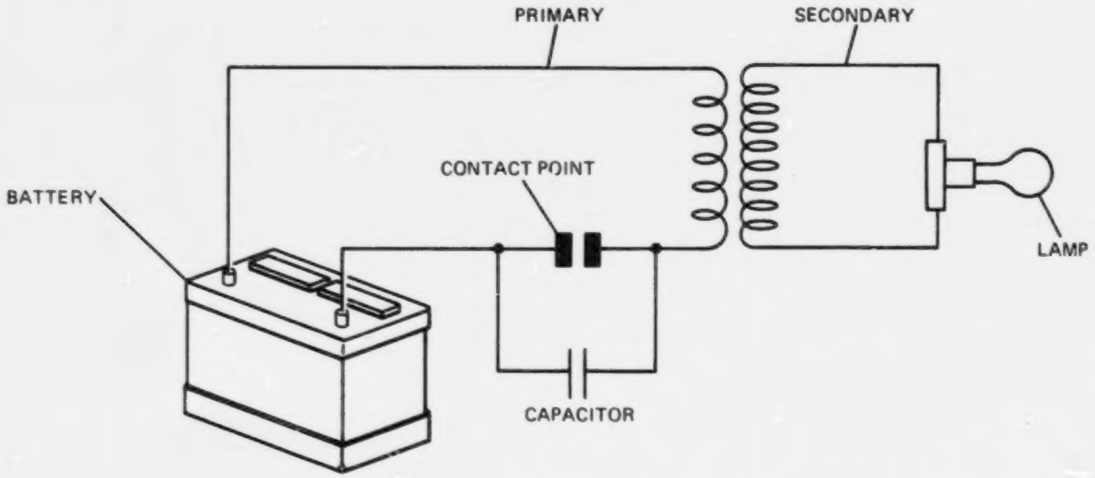


Figure 15-1. Principles of Self-Induction.

the current stops flowing, the magnetic field collapses. This means that the lines of force are moving toward the wires from which they came. The lines of force are moving in the reverse direction from when the magnetic buildup took place. This means that the countervoltage induced in the adjacent wire loops also will be reversed. Because it is reversed, it is in the same direction as the original voltage. The countervoltage opposes a decrease of current. The countervoltage always opposes any change in voltage, any change in current flow. During buildup, it opposes the increasing current flow. During collapse, it opposes any decreasing current flow.

(7) The effect of countervoltage during magnetic collapse can cause severe arcing at the switch, or contacts, used to open the circuit of the electromagnet. For example, in figure 15-1, when the contacts are opened, the countervoltage produced by the collapsing magnetic field will be great enough, if the electromagnet has enough turns, to push current across the opening contacts so that an arc occurs. This arc not only tends to burn the contacts, it also slows down the speed of magnetic-field collapse. The use of a capacitor (formerly referred to as a condenser) across the contacts protects them from arcing and speeds up the magnetic-field collapse.

b. Capacitor Action (Fig. 15-2).

(1) The capacitor has the capacity to store electrical charges briefly; therefore, it acts as a storage place for the surge of current caused by the countervoltage during magnetic collapse. Instead of arcing across the contacts, the current enters the capacitor.

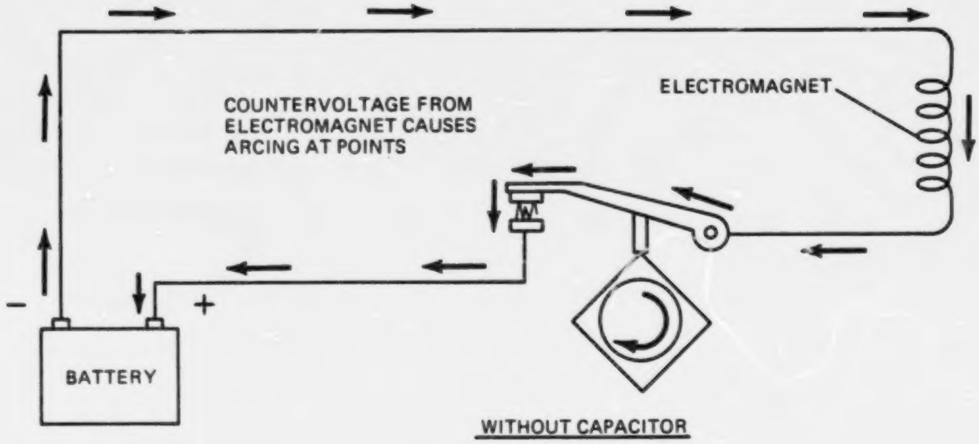
(2) The capacitor consists essentially of a pair of metallic plates separated by insulating material. In actual construction, the automotive capacitor is made up of two long strips of lead or aluminum foil wrapped into a winding with insulating paper between them. One strip of foil is connected to the capacitor can, the other is attached to a terminal.

(3) In operation, the foil strips serve as a large area into which free electrons (electric current) can move. For instance, suppose that the contacts are just opening. This interrupts the current from the battery, and a magnetic collapse starts. With the movement of the collapsing lines of force across the turns of wire in the electromagnet, a countervoltage is produced in the electromagnet that attempts to continue the current flow. However, instead of this current flowing across the contacts in an arc, it flows into the capacitor. One of the foil strips (the one connected to the negative side) accepts large numbers of free electrons (flow of current). These free electrons flow onto the strip. As they do so, they give the strip a negative charge. This negative charge repels electrons from the other strip so that it becomes positive.

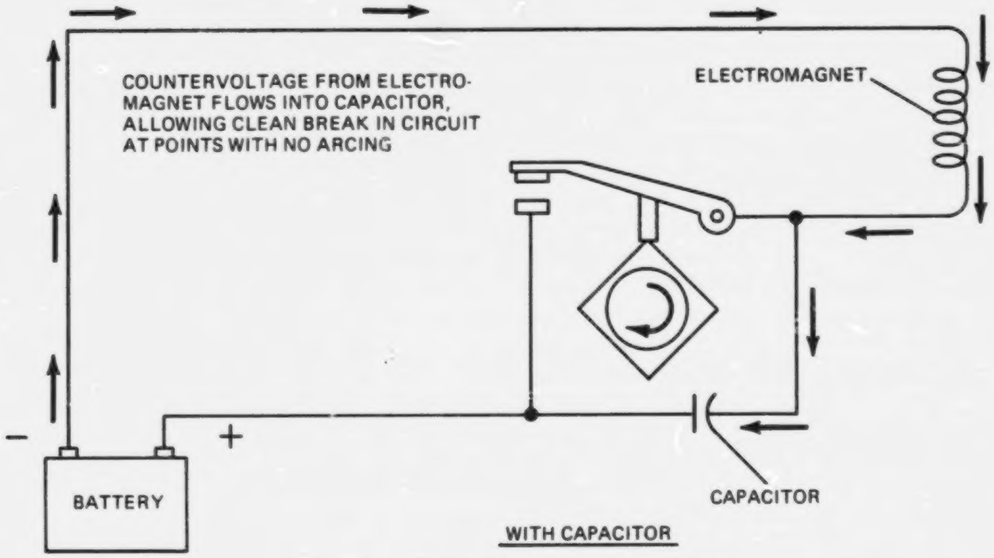
(4) The capacitor tends to prevent an arc at the contacts. It also tends to hasten the collapse

TA233585

312


COUNTERVOLTAGE FROM
ELECTROMAGNET CAUSES
ARCING AT POINTS
ELECTROMAGNET
−
+
BATTERY

WITHOUT CAPACITOR


COUNTERVOLTAGE FROM ELECTRO-
MAGNET FLOWS INTO CAPACITOR,
ALLOWING CLEAN BREAK IN CIRCUIT
AT POINTS WITH NO ARCING
ELECTROMAGNET
−
+
BATTERY
CAPACITOR

WITH CAPACITOR

Figure 15-2. Capacitor Action.

of the magnetic field. It does this because it soon becomes charged and thereby opposes any further current flow. In a sense, it acts like a spring to bring the current to a quick stop.

(5) If no other external action took place to change the conditions, the capacitor then discharges back into the electromagnet. As it does, there would be a magnetic buildup (opposed by a countervoltage), followed by a magnetic collapse as the capacitor completes discharging (again opposed by a countervoltage). The result is a rapid swing of current back and forth as it moves first in one direction and then in the other. Each time, the capacitor charges and discharges. And each time the amount of current would be a little less, as some of it is used up in heating the electromagnet. Shortly, the alternations would stop. In actual operation, they end in a fraction of a second.

c. Mutual Induction (Fig. 15-1).

(1) If a second winding were placed close to the first and connected to a lamp of the proper size, as shown in figure 15-1, the effect of the

TA233586

313

magnetic buildup and collapse as the contacts are closed and opened is obvious. For example, when the contacts are closed, a magnetic field builds up. This magnetic field moves across the second (or secondary) winding when it builds up. This induces a voltage in the secondary winding so that a current flows through it and through the lamp. If the lamp is of the right size, it will light up momentarily because the magnetic field does not take long to build up.

(2) When the contacts are opened, the magnetic field collapses and again moves across the secondary winding, inducing a voltage that causes the lamp to flash momentarily.

(3) With a capacitor (fig. 15-2), the lamp would be brighter as the contacts opened. The reason for this is that the capacitor speeds up the magnetic collapse. The lines move faster across the secondary winding in collapsing because of the capacitor effect. Faster-moving lines mean a higher voltage and more current, which, in turn, means a brighter light.

15-3. Ignition System.

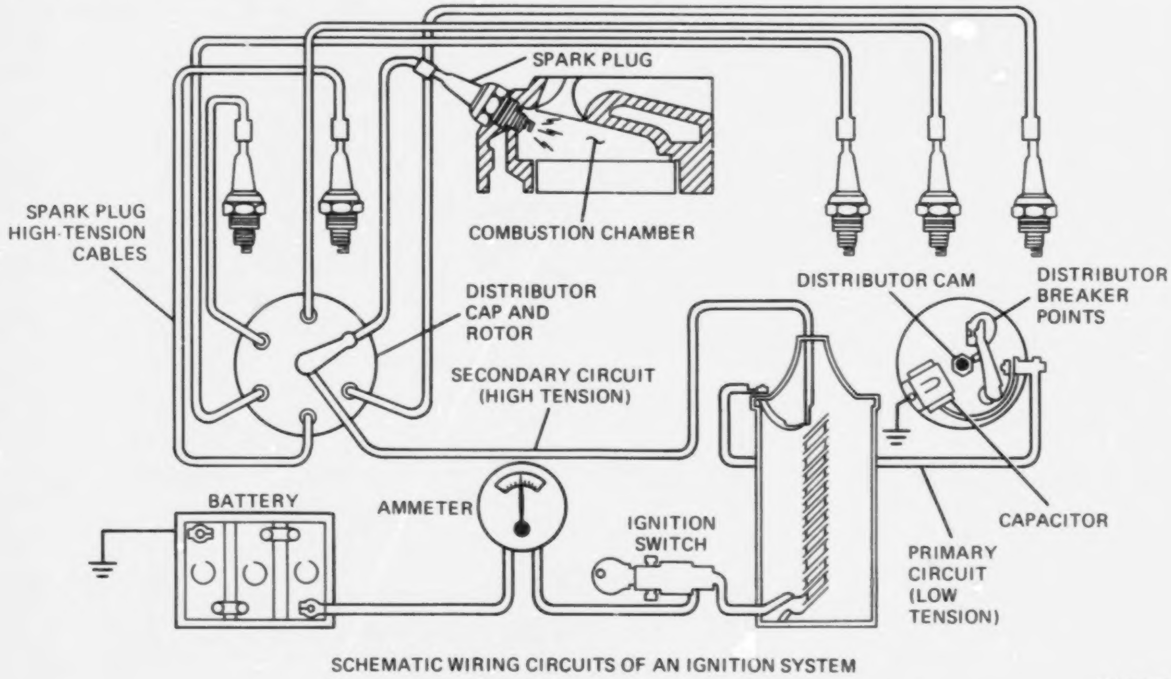
a. General. Figure 15-3 shows most of the essentials of an ignition system. Not shown in the illustration are the means of opening and closing the contacts and the means of distributing the induced high-voltage surges from the secondary to the spark plugs in the various cylinders. An actual diagram of an ignition is shown in figure 15-3. Note the functions of the various components in the system.

b. Battery. The battery and generator furnish the source of voltage and current for the ignition system. The battery is required when first starting, but, after the vehicle starts moving, the generator takes up the ignition load.

c. Ignition Switch (Fig. 15-4). The ignition switch enables the driver to turn the ignition on for starting and running the engine and to turn it off to stop the engine. Most modern configurations of ignition switches incorporate four positions that serve the following functions.

(1) *Off.* The off position shuts off the electrical system. Certain systems such as the headlights usually are not wired through the ignition switch and will continue to operate.

(2) *Accessory.* The accessory position turns on the power to the entire vehicle electrical system with the exception of the ignition system.


SPARK PLUG
COMBUSTION CHAMBER
SPARK PLUG HIGH-TENSION CABLES
DISTRIBUTOR CAP AND ROTOR
SECONDARY CIRCUIT (HIGH TENSION)
DISTRIBUTOR CAM
DISTRIBUTOR BREAKER POINTS
BATTERY
AMMETER
IGNITION SWITCH
CAPACITOR
PRIMARY CIRCUIT (LOW TENSION)

SCHEMATIC WIRING CIRCUITS OF AN IGNITION SYSTEM

Figure 15-3. Typical Automotive Ignition System.

TA233587

314

BEST COPY AVAILABLE

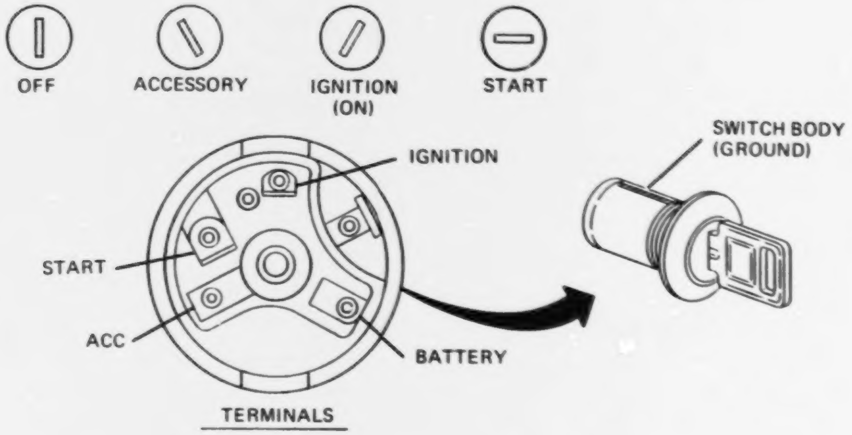

OFF
ACCESSORY
IGNITION (ON)
START
SWITCH BODY (GROUND)
IGNITION
START
ACC
BATTERY
TERMINALS

Figure 15-4. Ignition Switch and Positions.

(3) *Ignition On.* The ignition-on position turns on the entire electrical system, including the ignition switch.

(4) *Start.* The start position will energize the starter solenoid circuit to crank the engine. The start position is spring loaded to automatically return the switch to the ignition-on position when the key is released.

d. Ignition Coil. The ignition coil consists of a primary winding of a few hundred turns of relatively heavy wire that is about 0.04 inch in diameter (no. 18), plus a secondary winding of many thousands of turns of a very fine wire that is about 0.004 inch in diameter (no. 38), both assembled around a soft iron core and surrounded by a metal case topped with an insulating cap that carries the terminals (fig. 15-5). Because the countervoltage induced by the collapsing magnetic field is about the same value for each turn, the ratio of 100:1 (100 turns in secondary to 1 turn in primary), the secondary voltage could go 100 times as high as the primary. Because the countervoltages induced in the primary may reach 200 volts or more (by the rapid collapse of the magnetic field brought about by capacitor action), the secondary voltage could reach 20,000 volts. This high voltage is carried through the ignition distributor and distributed to the correct spark plug.

e. Ignition Distributor (Fig. 15-6).

(1) The ignition distributor has several jobs to do in the ignition system. First, it must close and open the primary circuit to produce the magnetic buildup and collapse in the ignition coil. Second, it times these actions so the resultant high-voltage surges from the secondary will be produced at the right time. Third, it must establish a timing sequence to direct the high-voltage surges to the proper spark plugs.

(2) The primary circuit through the distributor consists of a set of contacts and a capacitor connected across the contacts. The contacts are closed by spring pressure and

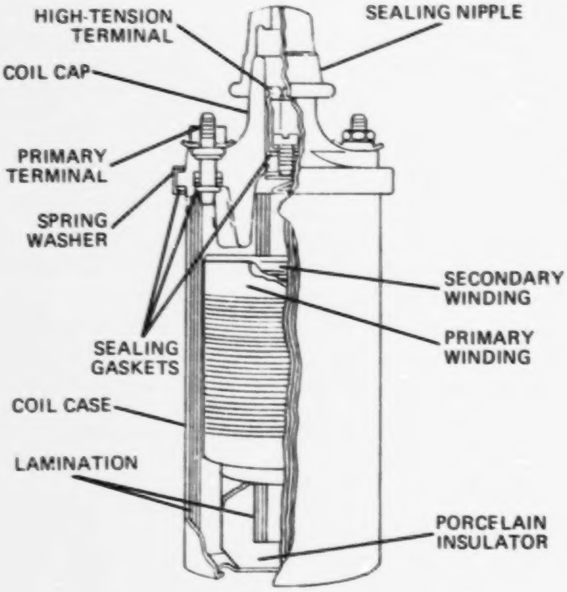

HIGH-TENSION TERMINAL
SEALING NIPPLE
COIL CAP
PRIMARY TERMINAL
SPRING WASHER
SECONDARY WINDING
PRIMARY WINDING
SEALING GASKETS
COIL CASE
LAMINATION
PORCELAIN INSULATOR

Figure 15-5. Ignition Coil Construction.

TA233588

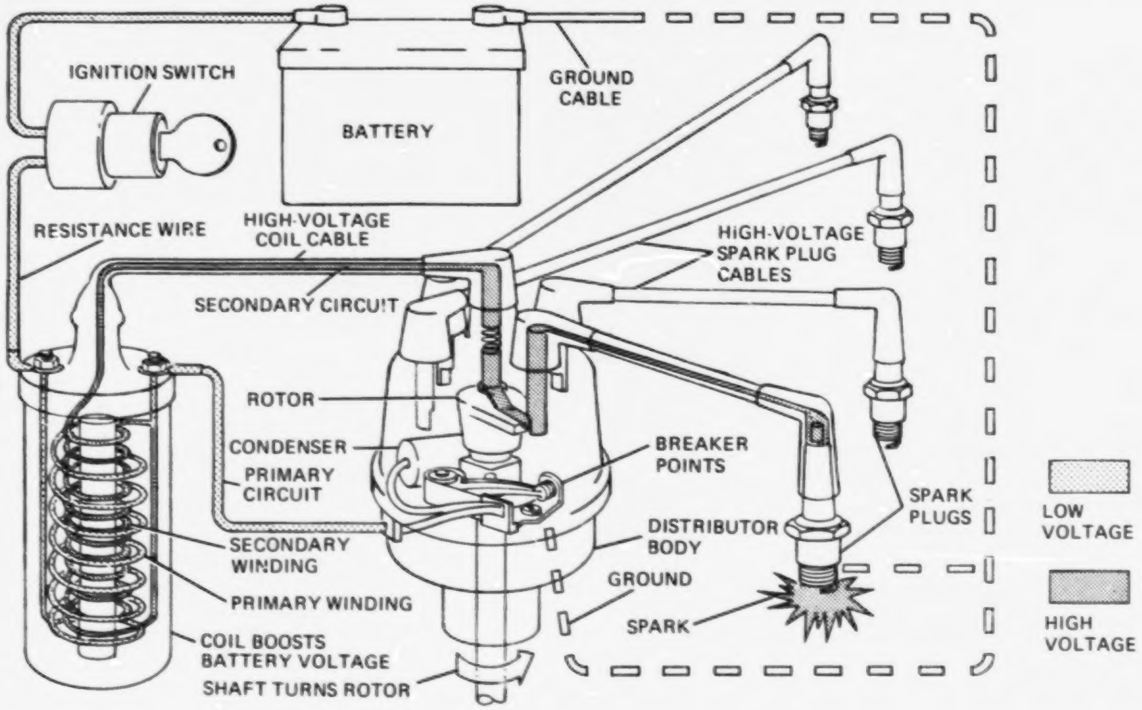

IGNITION SWITCH
BATTERY
GROUND CABLE
RESISTANCE WIRE
HIGH-VOLTAGE COIL CABLE
HIGH-VOLTAGE SPARK PLUG CABLES
SECONDARY CIRCUIT
ROTOR
CONDENSER
PRIMARY CIRCUIT
BREAKER POINTS
SPARK PLUGS
LOW VOLTAGE
DISTRIBUTOR BODY
SECONDARY WINDING
GROUND
PRIMARY WINDING
SPARK
HIGH VOLTAGE
COIL BOOSTS BATTERY VOLTAGE
SHAFT TURNS ROTOR

Figure 15-6. Ignition Distributor.

opened by a cam driven through the distributor shaft from a gear on the engine camshaft. Often, the oil pump is driven from the same gear. As the cam rotates, the cam lobes move around under the contact arm, causing the contacts to open and close.

(3) The secondary circuit through the distributor consists of a rotor mounted on top of the cam and a cap with high-tension terminals. In action, the rotor turns with the cam, connecting through its metal segment between the center high-tension terminal and the various outer high-tension terminals. This directs the high-voltage surges from the coil (which enter through the center high-tension terminal) to the various engine spark plugs (which are connected, in firing order, to the outer high-tension terminals).

f. Spark Plugs (Fig. 15-7). The spark plug consists of a porcelain insulator in which there is an insulated electrode supported by a metal shell with a grounded electrode. Several types of spark plugs have been used. They have the simple purpose of supplying a fixed gap in the cylinder across which the high-voltage surges from the coil must jump after passing through the distributor.

(1) The heat range of spark plugs is very important because a plug that runs too cold will accumulate heavy coatings of carbon (unburned gasoline), while a plug that runs too hot soon will burn up. Figure 15-7 illustrates the meaning of heat range. When the heat path from the center electrode to the cylinder head is long, the plug will run hotter. When the path is short, the heat can escape more readily and the plug runs cooler.

(2) In addition to the initial firing of the plug, there is an additional discharge of current at the spark plug caused by the oscillation of current in the primary circuit between the coil winding and condenser. This current discharge after the initial firing is not only unnecessary for operation but also causes undue spark plug deterioration and radio interference. This discharge of current can be shortened by using a resistor spark plug. A resistor spark plug (fig. 15-8) incorporates a resistor (about 10,000 ohms) into its insulator in series with the electrode.

TA233589

316

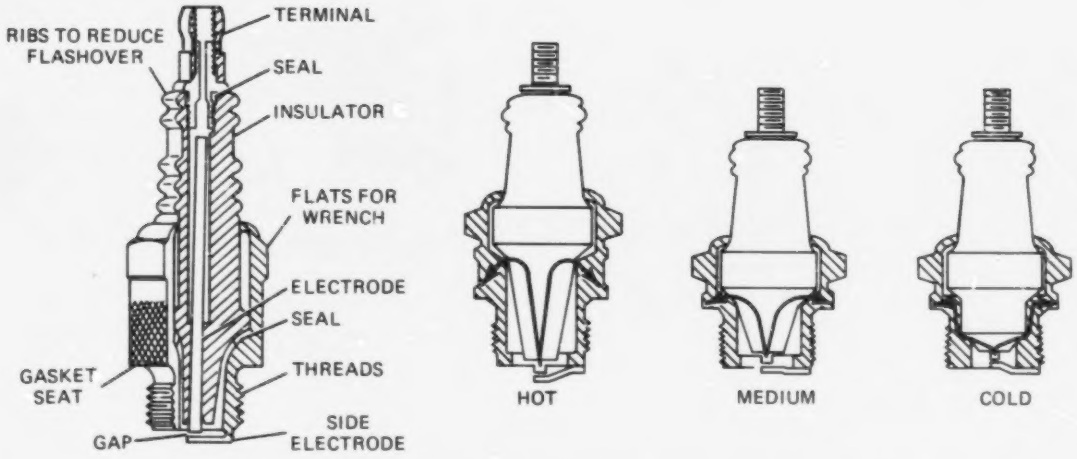

RIBS TO REDUCE FLASHOVER
TERMINAL
SEAL
INSULATOR
FLATS FOR WRENCH
ELECTRODE
SEAL
THREADS
GASKET SEAT
GAP
SIDE ELECTRODE
HOT
MEDIUM
COLD

Figure 15-7. Typical Spark Plug Construction and Heat Range Descriptions.

(3) Some spark plugs incorporate an auxiliary (booster) gap in the top terminal. This gap allows the coil to build a higher voltage and reduce misfiring, especially when spark plugs are dirty or fouled. A booster gap spark plug is shown in figure 15-9.

g. Ballast Resistors (Fig. 15-10). A ballast resistor is used between the ignition switch and the points. It effectively will control primary ignition voltage to prevent premature burning of the points. It contains a resistor element inside of a ceramic casing. The resistor element is made of

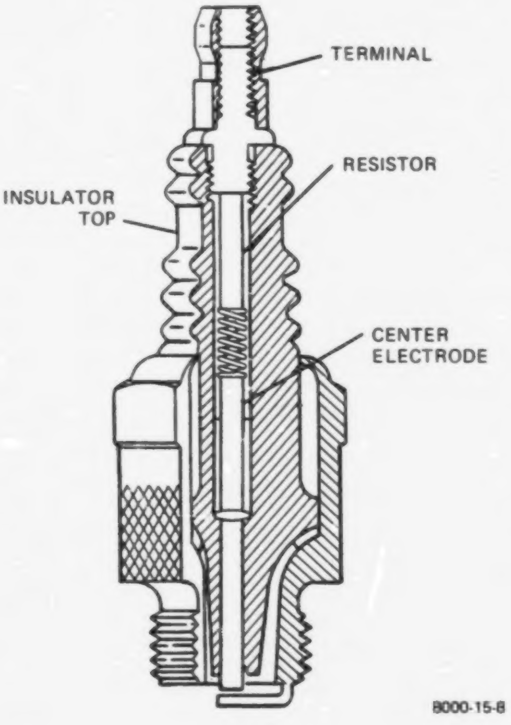

TERMINAL
RESISTOR
INSULATOR TOP
CENTER ELECTRODE
8000-15-8

Figure 15-8. Resistor Spark Plugs.

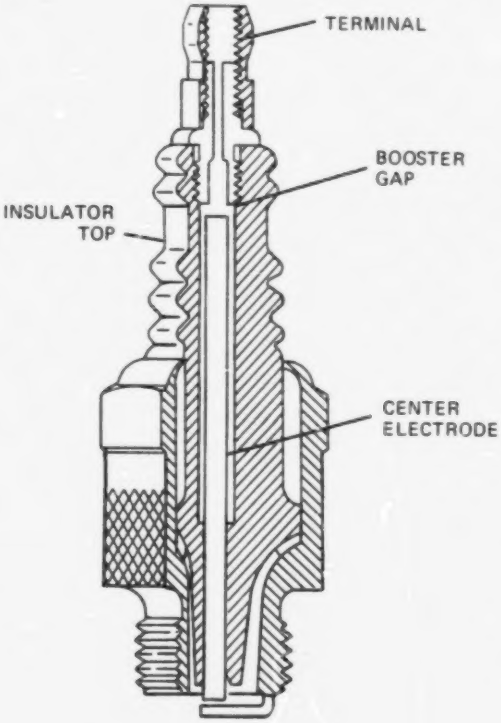

TERMINAL
BOOSTER GAP
INSULATOR TOP
CENTER ELECTRODE

Figure 15-9. Booster Gap Spark Plugs.

TA233590

317

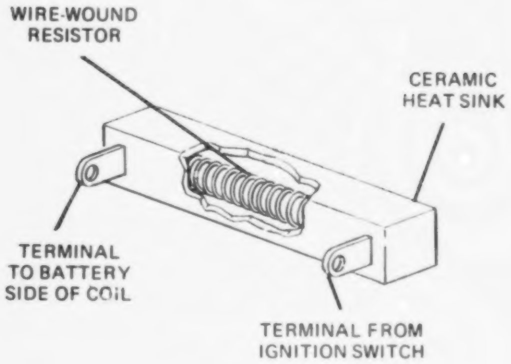

WIRE-WOUND RESISTOR
CERAMIC HEAT SINK
TERMINAL TO BATTERY SIDE OF COIL
TERMINAL FROM IGNITION SWITCH

Figure 15-10. Ballast Resistor.

a special material that increases proportionately in resistance to any temperature increase. The ballast resistor is bypassed during engine starting. This is done to compensate for the large voltage drop experienced during engine cranking. This large drop lowers available voltage below the threshold voltage required for ignition system operation, thus inhibiting spark plug firing. The ballast resistor is then placed back into the circuit as the engine is started.

(1) The points open and close slowly at low engine speeds. The longer duration of point closure tends to make the ballast resistor heat up, causing a proportional increase in resistance. The increase in resistance, in turn, reduces the voltage to the points. This is desirable because full voltage is not needed at low speeds, where there is a longer coil-saturation period. Full voltage would cause the points to burn.

(2) At high engine speeds the points open and close quickly. The short duration of point closure tends to cool the ballast resistor. This causes a decrease in resistance, which, in turn, increases the voltage to the points. This is desirable because of the short coil saturation period at high speeds.

h. Secondary (Spark Plug) Cables (Fig. 15-11). The secondary ignition cables carry the high-voltage electric current to the spark plugs.

(1) An ignition cable in its simplest form consists of a solid or stranded conductor of steel or copper that is surrounded by a heavy insulation of neoprene, hypalon, or silicon rubber. The design of the insulating material is important because of the high-voltage electric current. A poorly designed insulating material will leak electric current through it, causing spark plug misfire. This is true particularly in damp weather or when the insulation is subjected to high engine compartment temperatures.

(2) The secondary cable in its simplest form usually is inadequate for modern applications because the high voltage creates radio signals that interfere with TV and radio reception. The most common alternative is TVRS secondary cable. Rather than a conventional insulated wire, the TVRS cable is made of a fiberglass or linen

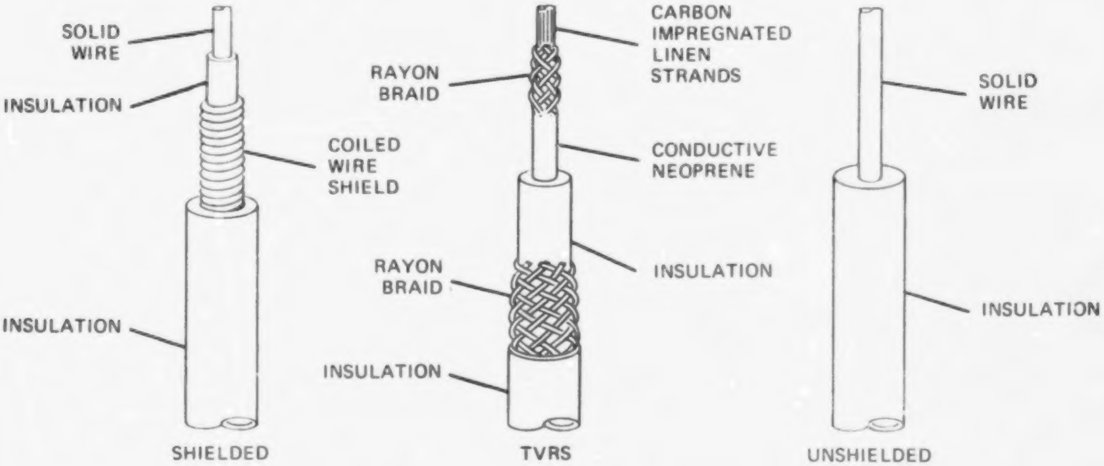

SOLID WIRE
INSULATION
COILED WIRE SHIELD
INSULATION
SHIELDED
RAYON BRAID
CARBON IMPREGNATED LINEN STRANDS
CONDUCTIVE NEOPRENE
INSULATION
RAYON BRAID
INSULATION
TVRS
SOLID WIRE
INSULATION
UNSHIELDED

Figure 15-11. Secondary Cable Construction.

TA233591

stranding that is filled with carbon. The insulation usually has a braided structure of rayon molded into it to increase strength. TVRS cable has a very high resistance value that effectively eliminates radio interference, but is very susceptible to conductor breakage if not handled carefully.

(3) An alternative to TVRS cable is shielded solid conductor cable. This type of cable is a solid conductor encased by a layer of insulation. The cable is then encased in a metallic shielding and an outer layer of insulation. This type of secondary cable, though very expensive, is very strong and widely used in military vehicles.

15-4. Multiple Contact Distributors.

a. General. Distributors may have more than one set of contacts. Some distributors use two sets in parallel for longer contact closing and higher magnetic strength of the coil. Others may use two sets for alternate firing of cylinders. Still others have two sets for dual ignition or for operation of two semi-independent ignition systems.

b. Parallel Operation (Fig. 15-12). To counteract the bounce, or chatter, of the breaker arm and to prevent overload of the contact points, two breakers can be connected in parallel and adjusted to open at the same time. If one pair of contacts has a tendency to bounce open at high speed, it is likely that the other pair will not bounce at exactly the same instant. Therefore, the circuit will be closed more positively than it would be with only one pair of contacts. The breaker arms also can be connected in parallel but made to operate progressively. That is, they are so set with respect to the cam lobes that one arm opens its contacts slightly before the other. The circuit actually is not broken until the second set of contacts open. Both sets of contacts are open for a shorter period of time than they are in simultaneous operation. This allows the ignition coil a slightly longer period of time in which to buildup. The breakers are arranged for progressive parallel operation.

c. Alternate Operation (Fig. 15-13). This is another arrangement that increases the time of contact and allows better magnetization of the coil. The two pairs of contacts still operate electrically in parallel, but use a cam with only half as many lobes as there are cylinders to be fired. The breakers are so arranged around the cam that one pair of contacts will close almost immediately after the other pair has opened. Thus, the two sets of breaker contacts almost overlap each other's movements so there is no waste of time. Shortly after one pair of contacts opens the circuit, the other pair closes it, so the coil can start to build up at once in preparation for the next spark. One set of contacts operates for half the cylinders and the other set for the other half.

d. Dual-Circuit Operation (Fig. 15-14).

(1) Another breaker arrangement, very similar in appearance to the one used for alternate operation, is used with two separate coils for

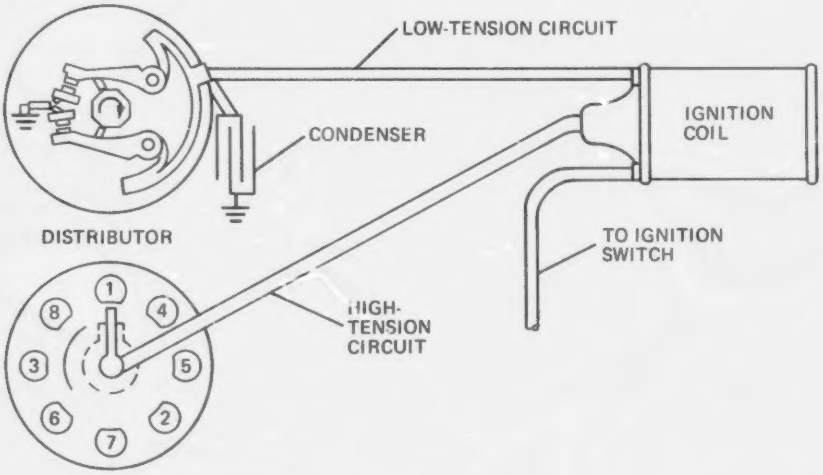


Figure 15-12. Parallel-Connected Multiple Contacts.

TA233592

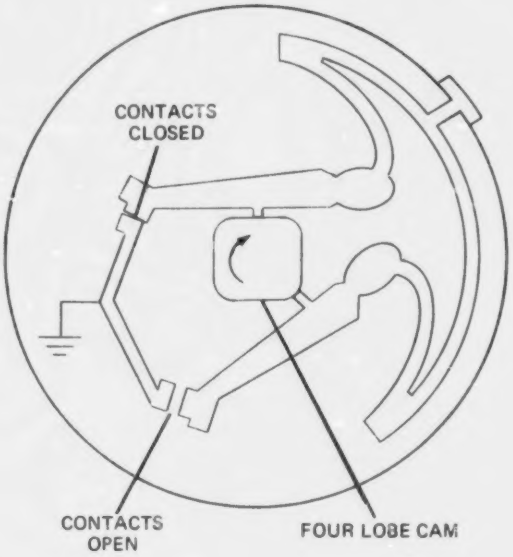


Figure 15-13. Alternately Actuated Multiple Contacts.

firing a large number of spark plugs. The breaker contacts operate alternately, but have no electrical connection between them except their common ground. This ignition interrupter permits two separate ignition systems: one system operating for one half of the cylinders and the other system for the other half. Here, the relation between the two sets of contacts is one of timing only, so that each will operate at the correct instant for the cylinders it serves.

(2) The distributor must take care of the two circuits. The high-tension lead from one coil enters the center of the distributor head at terminal 1 (figure 15-14), while the high-tension lead from the other coil enters at terminal 2, which is connected to a small ring that surrounds the central terminal. Two separate segments are molded within a double arm rotor, each one in contact with one of the high-tension terminals. One rotor segment completes its circuit to alternate spark plug terminals in the distributor cap, the other rotor segment taking the intervening terminals. Thus, there are two separate secondary circuits, 1 and 2, each furnishing current to half the spark plugs. The sparks from each coil are produced in exactly the same way as they are in a single system because each coil has its own set of breaker contact points. Two-circuit operation particularly is adaptable to V-type engines, with each set of contacts taking care of one bank of cylinders. Because each set of breaker contacts is independent of the other electrically, the breakers require synchronizing for proper operation. On some V-type engines, the two breaker arms open at irregular intervals, and therefore the manufacturer's specifications should be checked before any attempt is made to adjust the contact points.

e. Dual (Twin) Ignition (Fig. 15-15). Practically all automobiles have single ignition (one spark plug in each cylinder), although dual ignition has been used to advantage. No particular new theory is involved in producing and delivering current to the spark plugs in dual ignition. The principal difference is the use of two sparks to fire the fuel charge at two separated points within the same cylinder. If two sparks are delivered at widely separated points at the same instant, the fuel charge will start to burn from two points and meet in the center, thus securing more rapid and complete combustion. The firing of two spark plugs in each cylinder from one current source is sometimes called twin ignition. The dual is provided with two coils and two breaker arms operating on two circuits to supply sparks to two sets of spark plugs. To obtain the full advantage of dual ignition, the breaker contacts must be synchronized to fire two sparks simultaneously in each cylinder. The rotor segments then will deliver sparks to two opposite terminals in the distributor head, which are connected on two spark plugs within the same cylinder. Each rotor segment fires alternate terminals around the head; one segment firing the spark plugs on the right side of the cylinders and the other segment firing the spark plugs on the left side of the cylinders.

15-5. Transistorized Point Ignition (Fig. 15-16).

a. General. The transistorized point ignition system operates much the same way as the conventional ignition system. The difference is the addition of a transistor to carry coil current. The purpose of this ignition system is to lengthen the life of the contact points, which are traditionally the most troublesome component of the ignition system.

TA233593

320

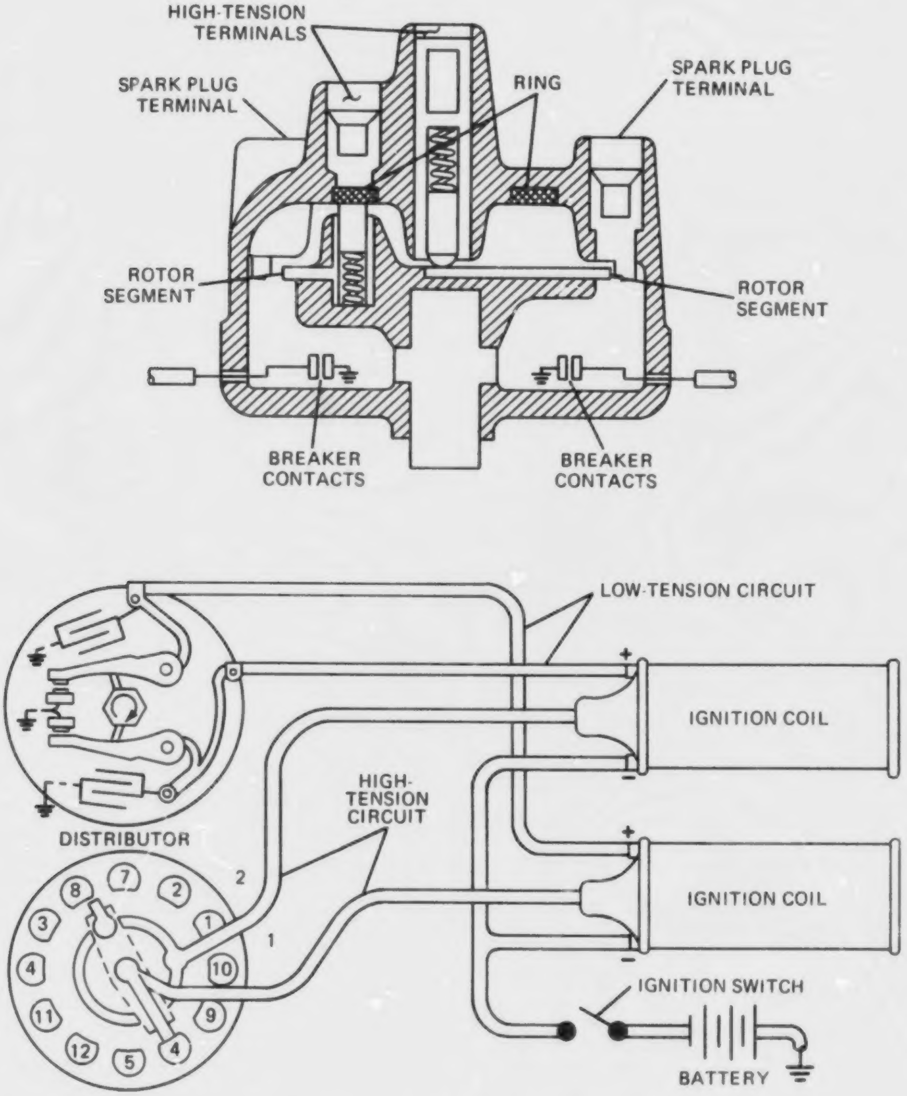

HIGH-TENSION TERMINALS
SPARK PLUG TERMINAL
RING
SPARK PLUG TERMINAL
ROTOR SEGMENT
ROTOR SEGMENT
BREAKER CONTACTS
BREAKER CONTACTS
LOW-TENSION CIRCUIT
+
IGNITION COIL
−
HIGH-TENSION CIRCUIT
DISTRIBUTOR
+
IGNITION COIL
−
IGNITION SWITCH
BATTERY
1
2
3
4
5
7
8
9
10
11
12

Figure 15-14. Dual-Circuit Contact Points.

b. Operation. The contact points handle the switching of the coil current (about 4 or 5 amperes) in the conventional ignition system. Despite the use of a condensor, there is a large amount of arcing that occurs between the points when they open and close. This arcing causes the points to burn and require regular replacement. By adding a transistor amplifier circuit to the ignition system, operation will be as follows:

(1) The transistor will handle the switching of the coil current electronically. There is no degradation to electronic components when they operate, providing they are operating within their limits.

(2) The contact points in the system handle the signal to the base of the transistor that initiates the switching of coil current. Because the switching current is so low (about 0.5 ampere) very little arcing occurs at the points, greatly extending their life.

(3) The points in a transistorized system have such a long life that the major concern with

TA233594

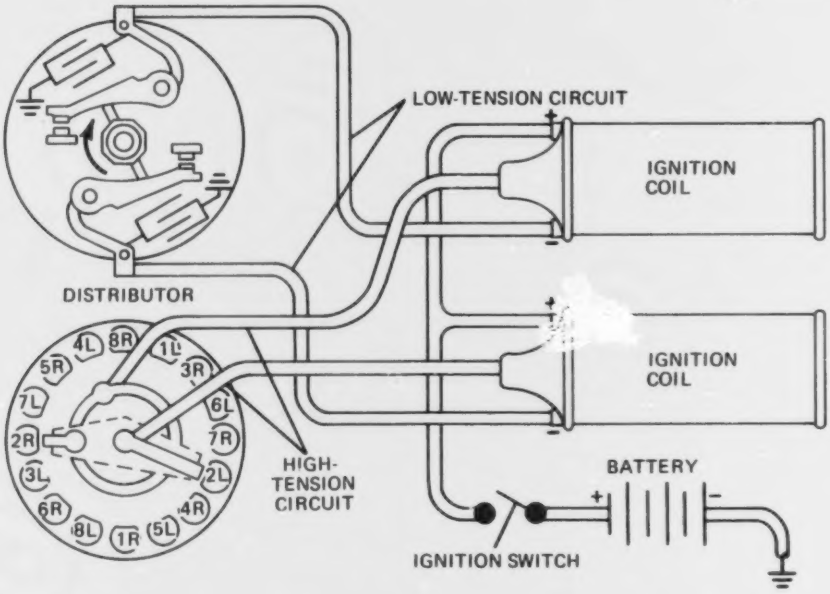


Figure 15-15. Twin-Ignition System.

them is the wearing down of the rubbing block, which causes them to lose their adjustment.

15-6. **Solid-State Ignition (Fig. 15-17).**

a. *General.* The recent rise of electronic ignition systems is due to the superiority of electronic ignition over conventional ignition systems in several major areas. These systems totally remove one area of maintenance from the ignition system, that of the ignition (contact) points. Also, because the electronic ignition system produces a higher voltage than the conventional system, the electronic ignition system usually can fire a fouled spark plug. In the area of high performance, the electronic ignition system is far superior in that its voltage does not deteriorate as quickly at high engine speeds as the conventional ignition system. Because the electronic ignition system does not contain ignition points that wear, ignition performance does not deteriorate with mileage.

b. *Description.* The electronic ignition system differs from that of a conventional ignition system in that it consists of a special pulse-sending distributor, an electronic control unit, a two-element ballast resistor, and a special ignition coil. Also, the ignition breaker points and capacitor used in the conventional ignition systems have been replaced by a gearlike piece called a reluctor and a pickup unit. The reluctor replaces the distributor cam used in the conventional distributor. The pickup unit is made up of a permanent magnet, a pole piece, and the coil.

c. *Operation.*

(1) The ignition primary circuit is connected from the battery, through the ignition switch, through the primary side of the ignition coil, to the control unit where it is grounded. The secondary circuit is the same as in the conventional ignition system. The magnetic pulse distributor also is connected to the control unit.

(2) As the distributor shaft rotates, the distributor reluctor turns past the pickup unit, and each of the eight teeth (on an eight-cylinder engine) on the reluctor pass near the pickup unit once during each distributor revolution. As the reluctor teeth move close to the pickup unit, voltage is induced into the pickup unit. That is, as a tooth on the reluctor passes the pickup coil, magnetic lines of force flow from the permanent magnet, through the pole piece, and through the reluctor back to the magnet. Voltage is induced in the windings as these magnetic lines of force pass

TA233595

322

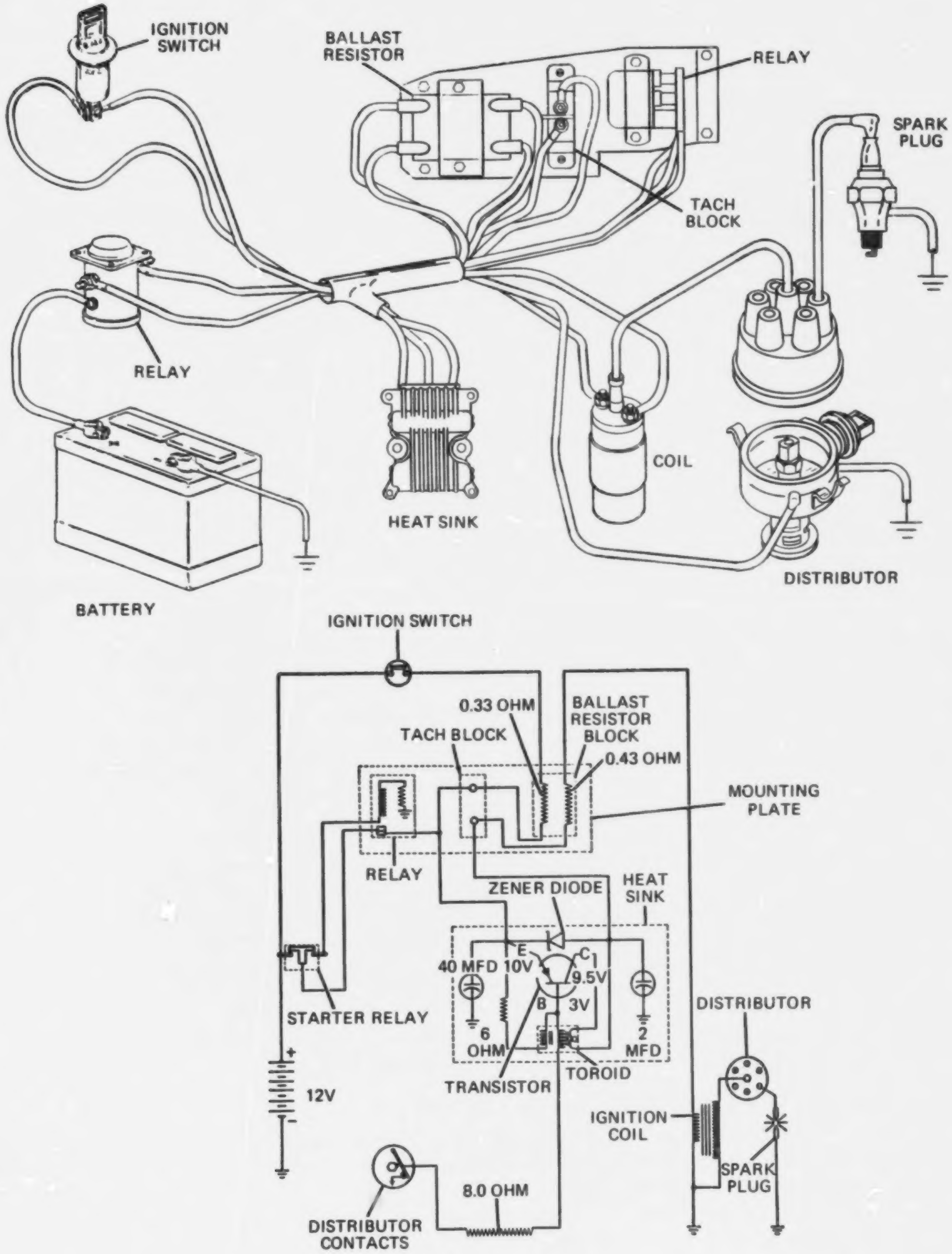
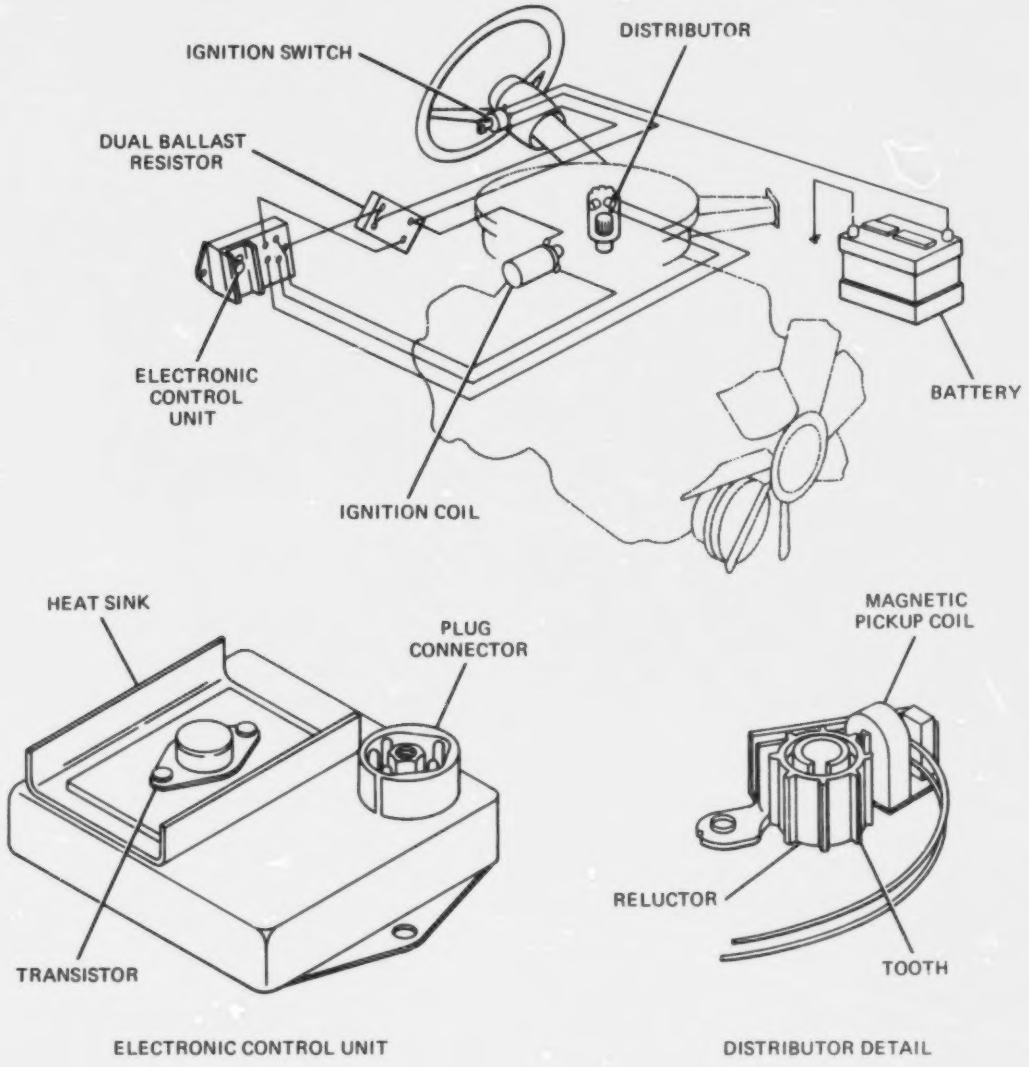

IGNITION SWITCH
BALLAST RESISTOR
RELAY
SPARK PLUG
TACH BLOCK
RELAY
COIL
HEAT SINK
DISTRIBUTOR
BATTERY
IGNITION SWITCH
0.33 OHM
BALLAST RESISTOR BLOCK
TACH BLOCK
0.43 OHM
MOUNTING PLATE
RELAY
ZENER DIODE
HEAT SINK
E
C
40 MFD
10V
9.5V
B
3V
6 OHM
2 MFD
TOROID
TRANSISTOR
STARTER RELAY
DISTRIBUTOR
+
12V
-
IGNITION COIL
SPARK PLUG
8.0 OHM
DISTRIBUTOR CONTACTS

Figure 15-16. Transistorized Point Ignition.

TA233596


IGNITION SWITCH
DISTRIBUTOR
DUAL BALLAST RESISTOR
ELECTRONIC CONTROL UNIT
BATTERY
IGNITION COIL
HEAT SINK
PLUG CONNECTOR
TRANSISTOR
MAGNETIC PICKUP COIL
RELUCTOR
TOOTH

ELECTRONIC CONTROL UNIT

DISTRIBUTOR DETAIL

Figure 15-17. Solid-State Ignition System.

through the pickup coil. This voltage is carried from the pickup coil to the control unit by the distributor leads. When the pulse enters the control unit, it signals the control unit to interrupt the ignition primary circuit. This causes the primary circuit to collapse and begins the induction of the magnetic lines of force from the primary side of the coil into the secondary side of the coil. This induction provides the required voltage to jump the spark plug gap and ignite the air-fuel mixture in the combustion chamber.

(3) As the tooth on the reluctor moves away from the pickup unit, the primary circuit is again completed. The magnetic field again is built up in the primary windings of the ignition coil, where it waits for another signal from the pickup unit.

(4) The buildup and collapse of the primary circuit takes place very rapidly. This is brought about by transistor action and the speed of the reluctor.

(5) The advantages of an electronic ignition system are that the transistors in the control unit can make and break the primary circuit much faster than conventional ignition points. Higher primary voltages can be used because this system

TA233597

can be made to handle higher voltages without harmful effects, whereas ignition points cannot. The quicker switching time of this system allows longer coil primary circuit buildup and longer induction time when the primary circuit collapses. This increased time allows the primary circuit to build up more current and the secondary circuit to discharge more current. The higher secondary current produces a hotter spark at the spark plug, which allows the engine to operate more efficiently.

15-7. Capacitive-Discharge Ignition (Fig. 15-18). The capacitive-discharge system offers several advantages over the other systems. This system is similar to full transistor-magnetic control, except that certain components have been added to the primary circuit. These are the power converter, capacitor, and thyristor or silicon controlled rectifier (SCR). The power converter has an output voltage of 250 to 300 volts. This voltage is used to charge the capacitor with the thyristor in its off condition. When the thyristor gate (1) receives a signal from the pulse generator, the circuit from the anode (2) to the cathode (3) is closed, and the capacitor immediately discharges at a high rate through the primary. A high secondary voltage can be reached about 100 times faster with the capacitive-discharge system than with the inductive systems. This decreases spark plug fouling, materially increasing potential spark plug life. Another advantage is that it uses less current than either the conventional system or the other solid-state systems. This means less demand on the battery during starts and a potentially longer battery life.

15-8. Ignition Timing Devices.

a. General. Spark advances are required so that the spark will occur in the combustion chamber at the proper time in the compression stroke. At high speed, the spark must appear earlier so the fuel-air mixture will have ample time to burn and give up its energy to the piston. At part throttle, when the fuel-air mixture is less highly compressed, a spark advance is required to ignite the slower-burning mixture in ample time for it to burn and deliver its power. Centrifugal and vacuum advance mechanisms produce these advances.

b. Vacuum Control (Fig. 15-19). The vacuum advance mechanism makes use of a vacuum chamber connected to the intake manifold and a vacuum diaphragm linked to the breaker plate assembly. The breaker plate is supported so it can turn back and forth a few degrees. When there is a wide-open throttle and little or no vacuum in the intake manifold, a full measure of fuel-air mixture is entering the cylinders and no spark advance beyond the centrifugal advance is needed. But when the throttle is closed partially, part of the fuel-air mixture is throttled off and the mixture entering the cylinders is less highly compressed. For satisfactory combustion, the spark must be advanced further beyond the advance produced by the centrifugal mechanism. To secure this additional advance, the

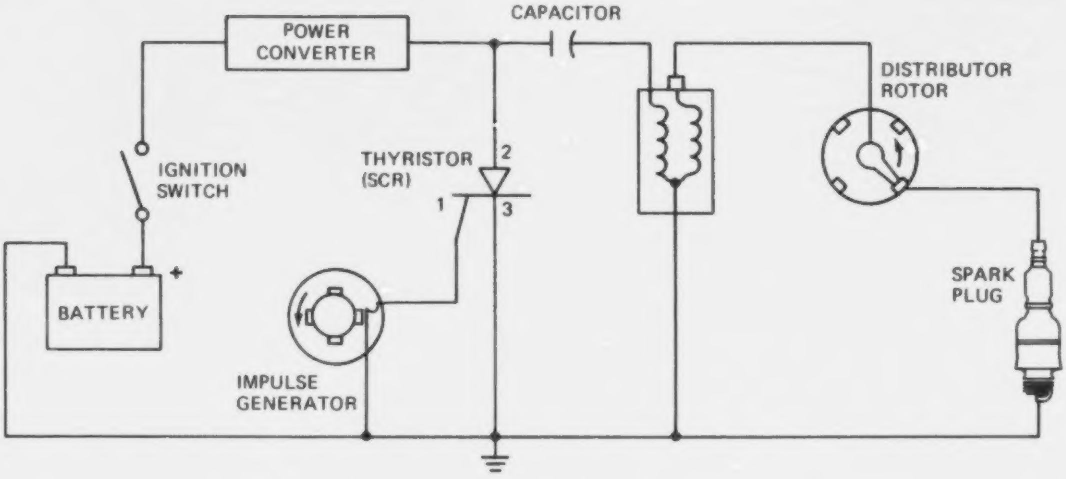


Figure 15-18. Capacitive-Discharge Ignition System.

TA233598

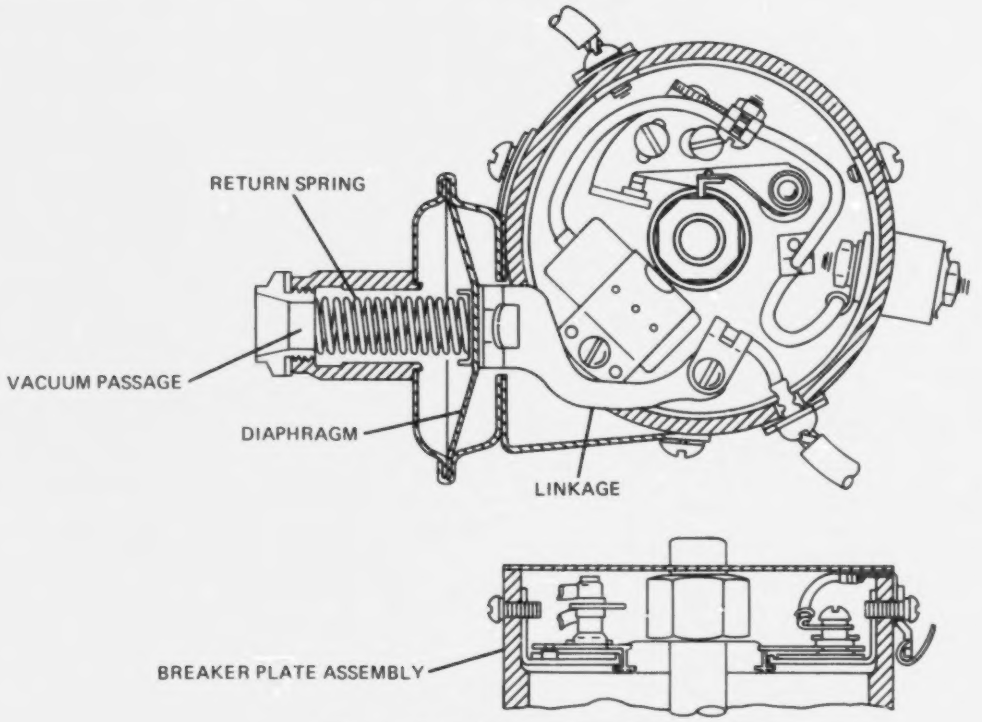


Figure 15-19. Vacuum Timing Controls.

vacuum line admits manifold vacuum to the vacuum passage, thereby allowing atmospheric pressure to push the diaphragm inward, compressing the return spring. This movement, through the linkage from the diaphragm, causes the breaker plate to be turned ahead so that the contacts are opened and closed earlier in the cycle. This advances the spark. Usually, the vacuum line is tapped into the carburetor just at the upper edge of the throttle valve when it is closed. This permits no advance on idle but causes a vacuum advance as the throttle valve is opened so its edge moves past the vacuum passage.

c. Centrifugal Control (Fig. 15-20). The centrifugal advance mechanism is located in the distributor housing and consists essentially of a pair of weights mounted on pins on a weight base and linked by weight springs to the advance cam. When idling, the springs hold the advance cam in a no-advance position. As speed increases, the centrifugal force on the weight causes them to move out. This action forces the toggles on the weights to move against the advance cam so the cam is pushed ahead against the spring tension. As the advance cam turns ahead, the breaker cam lobes open and close the contacts earlier in the cycle. This advances the ignition timing.

d. Computerized Control (Fig. 15-21). The trend in modern automotive design is to use a computer to control ignition advance. Electronic ignition is very adaptable to computer control because the amplifier circuit can be integrated right into the computer module. With this arrangement the ignition timing is regulated within the module by electronically regulating the signal from the distributor pickup to the amplifier. This is the job of the computer. The computer establishes the proper ignition timing based on signals it receives from various sensors on the engine. The sensors provide information such as engine speed, throttle position, coolant temperature, ambient temperature, and manifold vacuum. The computer is able to change ignition timing many hundreds of times per second in contrast to mechanical devices that are slow to react to the engine's needs. Because of this, a computer-controlled system of spark advance will allow the engine to be more responsive while running on leaner fuel mixtures. This will result in a cleaner running, more economical engine.

TA233599

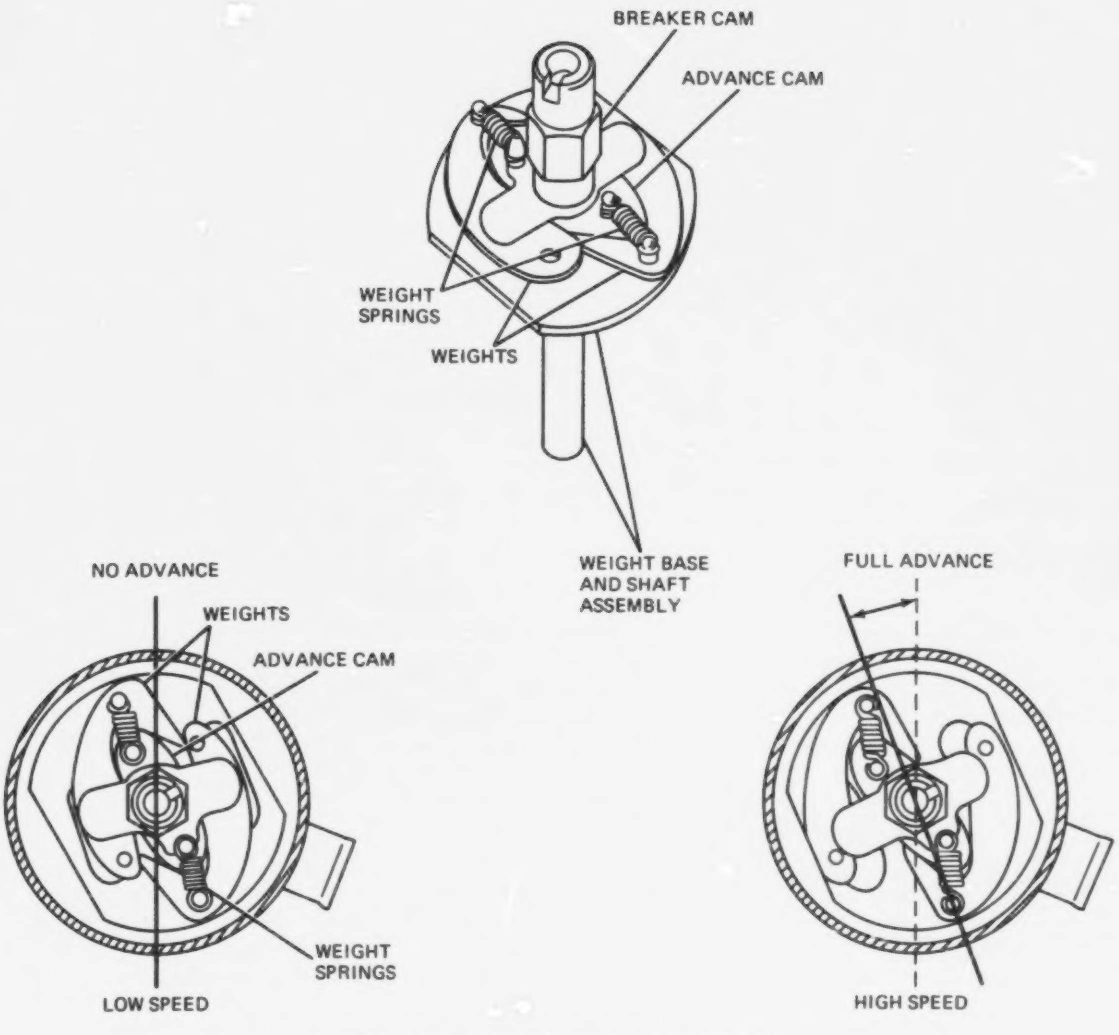

BREAKER CAM
ADVANCE CAM
WEIGHT SPRINGS
WEIGHTS
WEIGHT BASE AND SHAFT ASSEMBLY
NO ADVANCE
WEIGHTS
ADVANCE CAM
WEIGHT SPRINGS
LOW SPEED
FULL ADVANCE
HIGH SPEED

Figure 15-20. Centrifugal Timing Controls.

TA233600

527

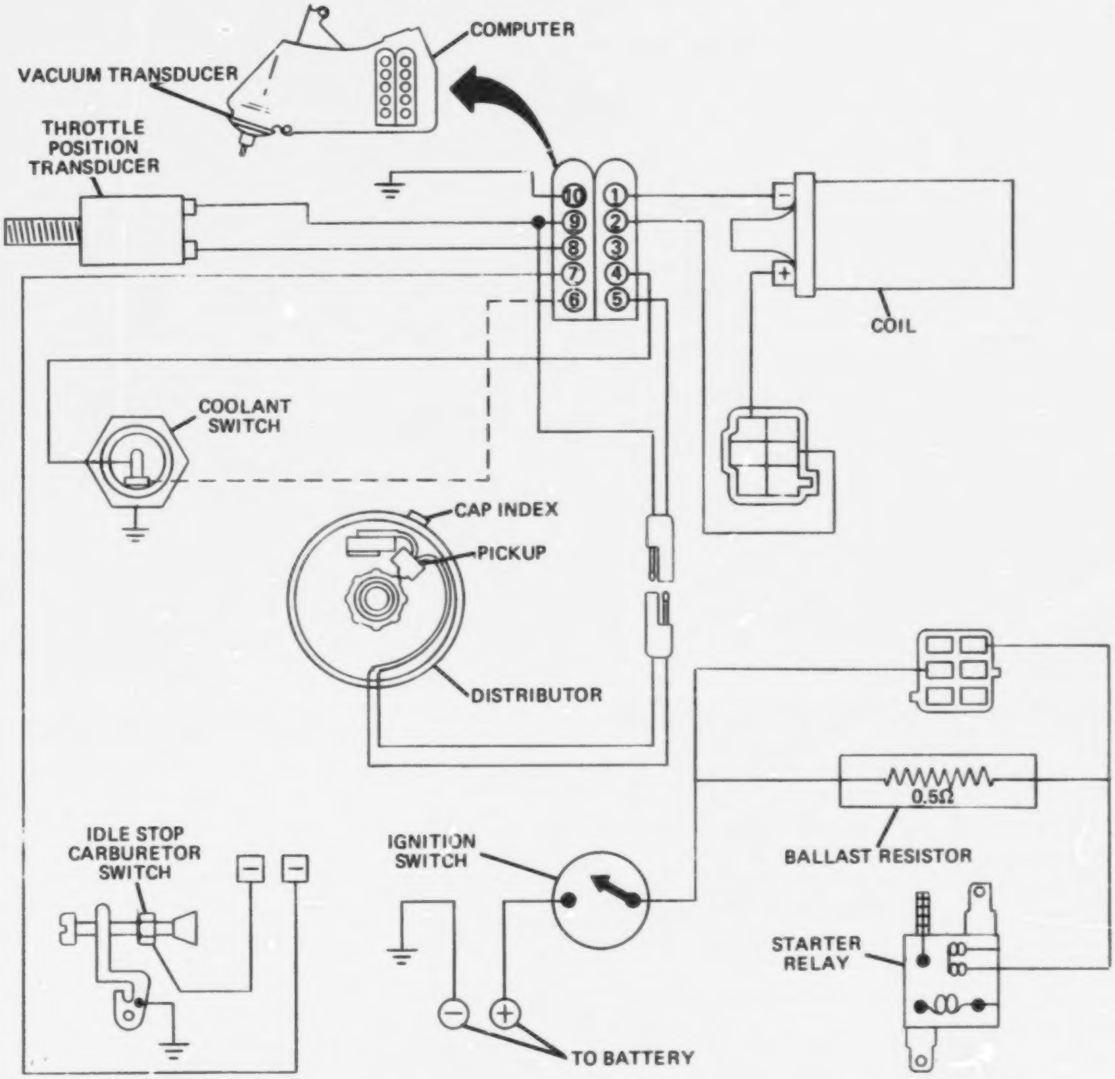

COMPUTER
VACUUM TRANSDUCER
THROTTLE POSITION TRANSDUCER
10
9
8
7
6
1
2
3
4
5
−
+
COIL
COOLANT SWITCH
CAP INDEX
PICKUP
DISTRIBUTOR
0.5Ω
BALLAST RESISTOR
IDLE STOP CARBURETOR SWITCH
IGNITION SWITCH
STARTER RELAY
TO BATTERY

Figure 15-21. Computerized Timing Control System.

Section II. MAGNETO IGNITION SYSTEMS

15-9. General (Fig. 15-22).

a. Ignition of the fuel-air mixture in the combustion chamber of the gasoline engine requires an electric spark. The electric spark can be produced in two ways: by magneto ignition or by battery ignition. The magneto is a compact combination of generator, ignition coil, and distributor. It requires no battery. Voltage is induced within the magneto by relative movement between a coil and the poles of a permanent magnet.

b. The problem in magneto ignition is to generate a spark of sufficient voltage to ignite the fuel-air mixture instantly and to synchronize the spark with the engine cycle so that maximum power will be realized from the combustion. The fundamental units are listed below:

TA233301

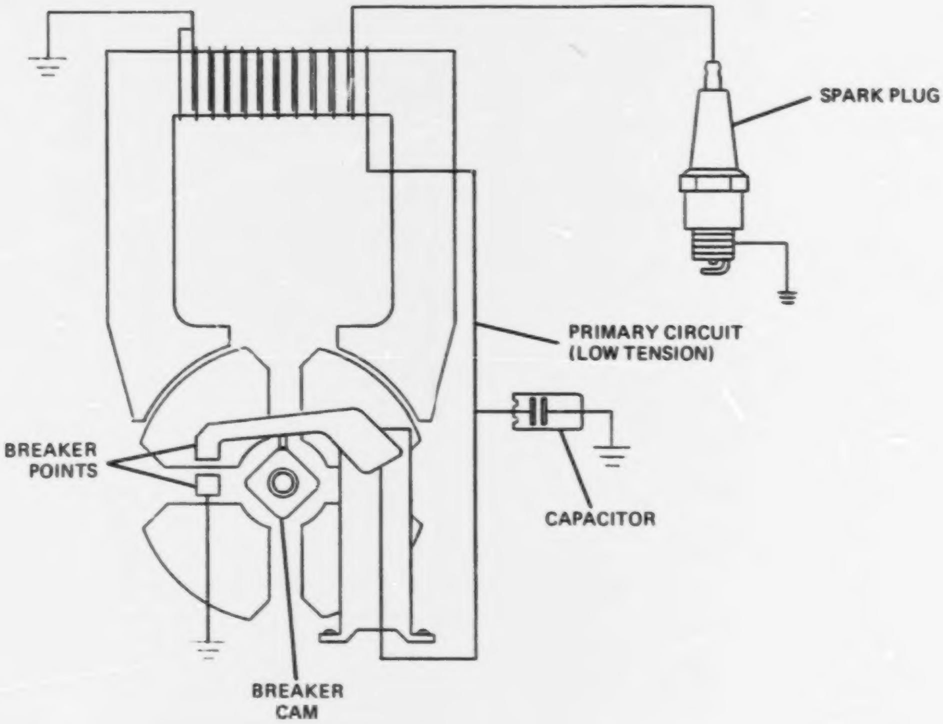


Figure 15-22. Typical Magneto System.

(1) A means of developing electricity.

(2) A transforming device to increase the voltage of the electricity developed.

(3) An interrupting device to determine the proper timing of the electrical impulses.

(4) A distributor to direct the electrical impulses in the proper order to the different cylinders.

(5) A spark gap in each cylinder in the engine.

(6) The proper wiring and switches to bring these units together to form the ignition system.

c. The first four units are contained within the magneto. The spark plug supplies the fifth unit, wiring and switches make up the sixth unit. The same four fundamental units that make up the magneto also can be classified broadly as just two parts: a generator and a transformer. The generator provides a means of inducing low voltage in a primary circuit. The transformer changes the low voltage of the primary circuit to the high voltage in a secondary circuit so that an extremely hot spark can be produced across the spark plug gap.

d. The magneto ignition system generally is reliable, requires little maintenance, and does not have a battery to run down or wear out. Its principal disadvantage is that it turns so slowly during the cranking of the engine that a hot spark is not produced. Therefore, a supplementary high-voltage source must be provided. This may be a booster magneto or a high-tension coil to which primary current is supplied by a battery. In some magnetos, an impulse starter is provided that produces high armature speeds at engine cranking speeds to provide a hot spark.

15-10. Source of Electrical Energy (Fig. 15-23). In studying the magneto, it should be understood that three things are necessary to induce voltage: an electrical conductor, a magnetic field, and relative motion between the field and the conductor. In the magneto, a permanent magnet supplies the magnetic field, a wire coil is the conductor, and the engine

329

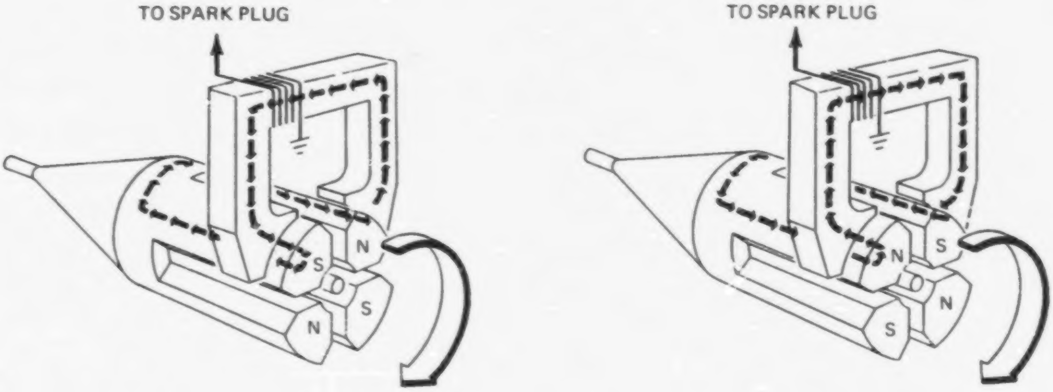


Figure 15-23. Magneto Generator.

provides mechanical energy for motion between the field and the conductor. There are two types of magnetos: armature-wound, in which the coil moves while the magnets are stationary; and the inductor type, in which the reverse is true, the magnets move and the coil is stationary. In the inductor type, for example, a rotor that is a permanent magnet is used to direct the magnetic field flow through the windings, first in one direction and then in the other. Because the winding is stationary, it is easier to make connections from it. Either type of construction satisfies the first requirement of an electric ignition system, that is, a means of developing electrical energy.

15-11. Transforming Device (Fig. 15-22). Most engines require about 15,000 volts at the spark gap in the cylinder. The problem when the magneto is used is to raise the low voltage induced in the conductor (primary winding) to the required high voltage. This is accomplished in the same way that it is in the battery ignition coil. When the current in the primary winding or conductor is at its maximum flow, the circuit is broken suddenly, collapsing the electromagnetic field set up around the primary circuit as the result of current flow. The lines of force in the field collapse at an extremely high rate of speed across the secondary winding, which is made up of many turns of fine wire, whereas the primary winding is composed of relatively few turns of coarser wire. This rapid movement of the lines of force across the secondary winding induces a momentarily high voltage in the secondary winding, in proportion to the ratio of the number of turns on the primary winding to the number on the secondary winding. This makes about 15,000 volts available at the spark gap.

15-12. Interrupting Device (Fig. 15-22).

a. Breaker Points. The interrupting device, which breaks the primary circuit when the high-voltage spark is desired, is a set of breaker points. One end of the primary winding is connected to a ground; the other to the insulated breaker point. When the points are closed, the circuit is completed through them to a ground; when open, the circuit is broken. Lobes on a cam actuate the breaker points, interrupting the primary circuit and timing the induction of maximum voltage in the secondary circuit. The cam is mounted on either the armature or rotating magnet.

b. Capacitor. When the breaker points are opened, the current then flowing in the primary circuit tends to arc across the points due to self-induction. This reduces the speed with which the circuit is broken and the magnetic field collapses. This action is controlled by inserting a capacitor in parallel with the breaker points. When the primary circuit is broken, the capacitor receives the surge of current and then, on discharging, reverses the normal flow of current. The capacitor thus hastens the collapse of the magnetic field around the primary winding and increases the amount of voltage induced.

TA233603

15-13. Distributor.

a. The magneto distribution operates much the same as the battery ignition distributor (para 15-3). The distributor rotor, which directs the electrical impulses in proper order to the cylinders, usually is driven through suitable gearing, at one-half crankshaft speed. This ratio ensures that each cylinder will be fired during the cycles of the engine. The cam is much larger than those used in battery ignition distributors and contains the contact spring and cam electrode that, together, serve the same purpose as the rotor segment in a battery ignition distributor. That is, the cam electrode connects the high-tension center electrode (connected to secondary of coil) to each of the outer distributor electrodes in turn. These outer electrodes are connected by high-tension leads to the spark plugs.

b. One end of the secondary winding is connected to the primary. The other end terminates at the high-tension insert, which is a piece of metal extending through the Bakelite case covering the coil. The high-tension voltage developed in the secondary coil passes through the insert to a contactor such as the high-tension contact spring in the magneto cover. From there, it goes to the center electrode and then, internally, through the distributor rotor to the outer electrodes. The rotor is timed so that the cam electrode will line up with the center electrodes to which spark plug leads are connected, at the proper time for igniting the fuel-air charges in the cylinders.

c. The spark plug assembly provides a gap where a surge of high voltage may cause a spark to ignite the fuel-air mixture. One spark plug electrode is connected to the high-tension cables from the distributor blocks; the other is fastened to a ground. Most air-cooled engines have two spark plugs for each cylinder and two separate magnetos for the ignition system. The second spark plug ensures better combustion and is added insurance against ignition failure.

d. The high-tension wires that conduct the current from the distributor blocks to the spark plugs are commonly called the ignition harness. As a magneto ignition system transmits a form of high-frequency current, radiations emanating from it during operation will interfere with radio reception if the ignition system is not shielded. This shielding is a metal covering of woven construction that surrounds the wires. Plain metallic shields cover the distributor blocks and booster coil. The shielding is grounded to the engine so that it can pick up the undesirable radiations from the magneto and carry them directly to a ground. The radiations are thus prevented from reaching the vehicle's radio aerial and interfering with reception.

15-14. Booster Coil. Magneto speed during cranking is not high enough to develop a hot spark. An external source of high-tension current for starting is provided, either by a booster magneto or by a high-tension coil, with the primary current being supplied by a battery. The coil method is most common. Current from the booster coil, which operates just like the coil in the battery ignition system, is conducted to the booster electrode of the magneto. This connects the booster coil with the magneto primary coil when the contacts open, thereby causing a current surge through the primary (from the booster coil), which produces a rapid change of magnetic field strength in the primary. This action induces in the secondary a high-voltage surge sufficiently strong to fire the plugs.

15-15. Magneto Switches (Fig. 15-24).

a. Because the magneto is self-energizing, it cannot be turned off by disconnecting it from some external source of energy as in the battery ignition system. Instead, the magneto coil must be grounded. Because one end of the magneto coil is grounded already, grounding the other (or breaker point) end effectively will prevent the magneto from producing high-voltage surges. This is accomplished by means of a grounding switch on the vehicle instrument panel. When the switch is turned off, contacts in the switch are closed and the magneto coil is grounded through them. The magneto, booster, and main-engine starter switches all are located together in the same housing. The main magneto switch actually has four positions because, in the application shown, four magnetos are used (fig. 15-24). The four positions are OFF (all magnetos grounded), A (two of the magnetos that fire the plugs in the accessory ends of cylinders are ungrounded and operative), F (the two magnetos that fire the plugs in the flywheel ends of the cylinders are ungrounded and operative), and BOTH (all four magnetos are operative).

331

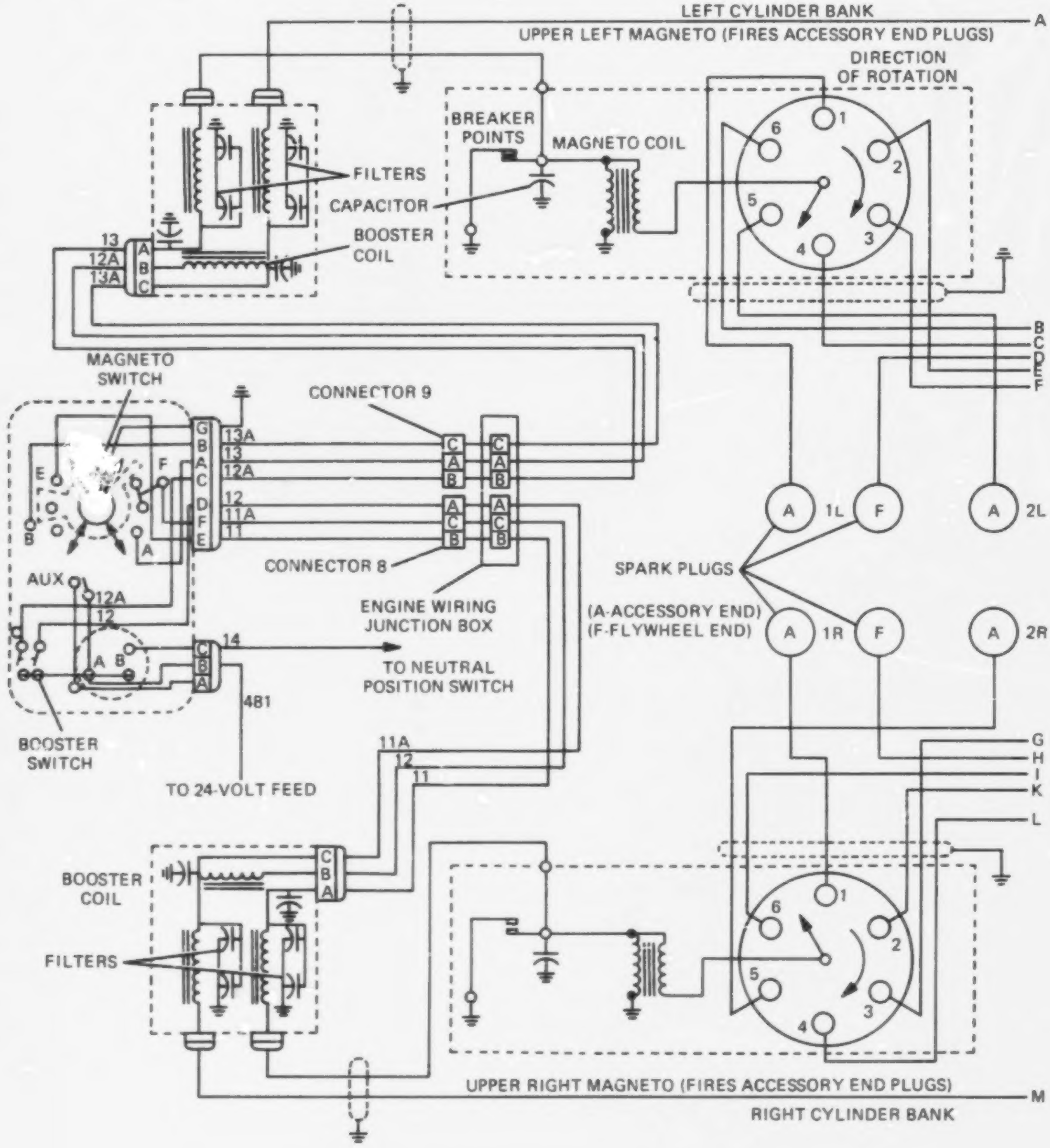

LEFT CYLINDER BANK
A
UPPER LEFT MAGNETO (FIRES ACCESSORY END PLUGS)
DIRECTION OF ROTATION
BREAKER POINTS
MAGNETO COIL
FILTERS
CAPACITOR
BOOSTER COIL
13
12A
13A
A
B
C
1
2
3
4
5
6
B
C
D
E
F
MAGNETO SWITCH
CONNECTOR 9
G
B
A
C
D
F
E
13A
13
12A
12
11A
11
E
F
B
A
AUX
12A
12
A
B
14
481
CONNECTOR 8
ENGINE WIRING JUNCTION BOX
TO NEUTRAL POSITION SWITCH
BOOSTER SWITCH
TO 24-VOLT FEED
A
1L
F
A
2L
SPARK PLUGS
(A-ACCESSORY END)
(F-FLYWHEEL END)
A
1R
F
A
2R
G
H
I
K
L
11A
12
11
BOOSTER COIL
FILTERS
C
B
A
UPPER RIGHT MAGNETO (FIRES ACCESSORY END PLUGS)
M
RIGHT CYLINDER BANK

Figure 15-24. Magneto Control System. (Part A)

b. The magneto switch is mounted in the same housing with the booster and the main-engine starter switch. This places the switches that must be operated for starting together. The starter switch, when operated, closes a relay that, in turn, brings the starter into operation. At the same time that the starter switch is operated, the booster switch also must be operated. This switch, just next to the starter switch, connects the booster coil to the circuit when closed. Both the starter switch and the booster switch are spring loaded and so placed that their levers must be brought down and pivoted toward each other for closing. Thus, both can be closed by the thumb

TA233604

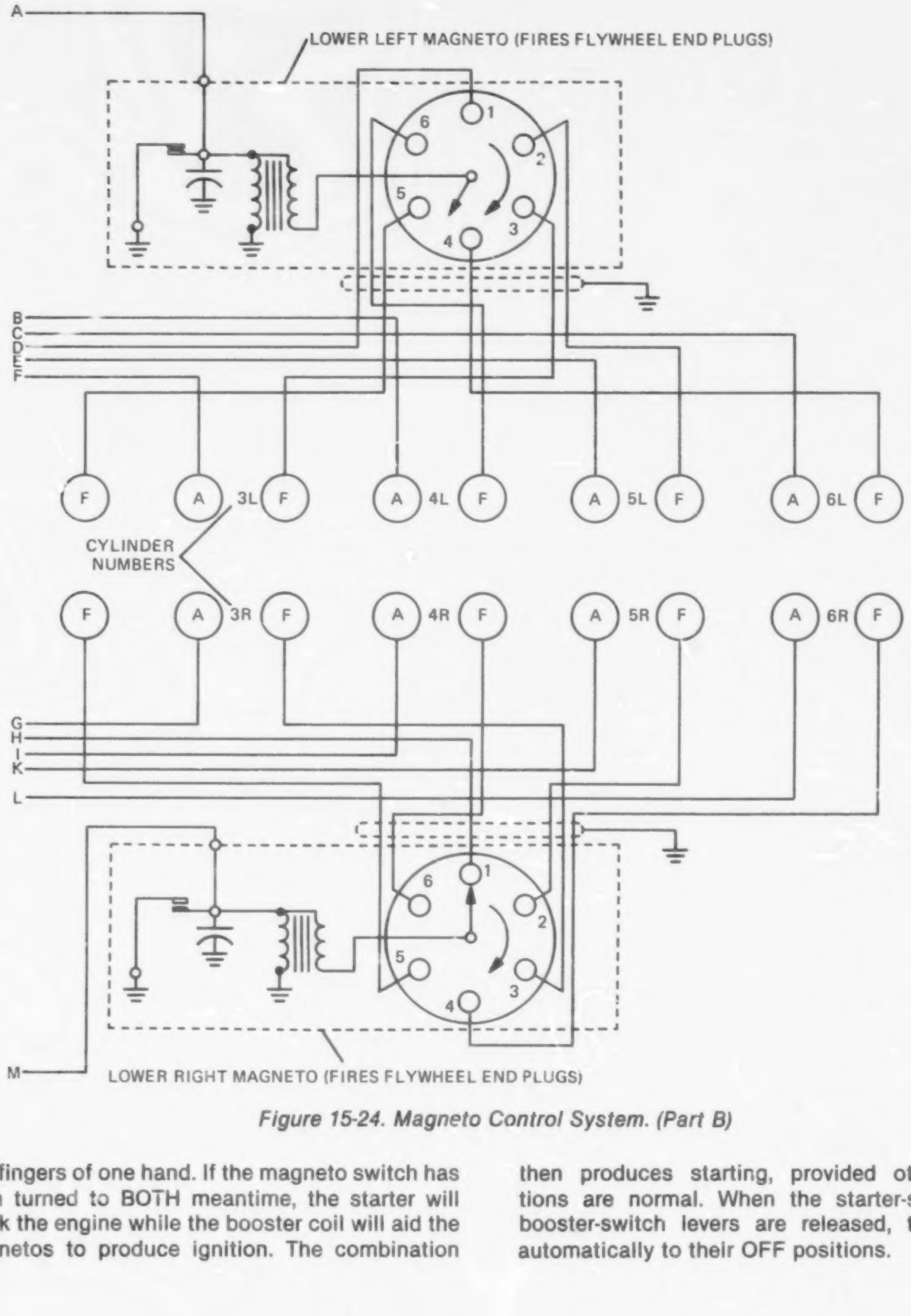

A
LOWER LEFT MAGNETO (FIRES FLYWHEEL END PLUGS)
1
2
3
4
5
6
B
C
D
E
F
F
A
3L
F
A
4L
F
A
5L
F
A
6L
F
CYLINDER NUMBERS
F
A
3R
F
A
4R
F
A
5R
F
A
6R
F
G
H
I
K
L
1
2
3
4
5
6
M
LOWER RIGHT MAGNETO (FIRES FLYWHEEL END PLUGS)

Figure 15-24. Magneto Control System. (Part B)

and fingers of one hand. If the magneto switch has been turned to BOTH meantime, the starter will crank the engine while the booster coil will aid the magnetos to produce ignition. The combination then produces starting, provided other conditions are normal. When the starter-switch and booster-switch levers are released, they return automatically to their OFF positions.

TA233605

Section III. WATERPROOFING IGNITION SYSTEMS

15-16. General. Because many vehicles must operate under very wet conditions and must be able to ford fairly deep waters, it is necessary to waterproof the ignition system. The system must be so watertight that, even though the components are immersed, they can continue to function normally and will not suffer any damage.

15-17. Description (Fig. 15-25). The distributor and ignition coil are sealed in a common housing and enclosed by a common cover. This application also has a means of ventilating the distributor, thus preventing the condensation of water and the formation of harmful chemicals. Otherwise, such chemicals might form due to the arcing that takes place between the rotor segment and the cap inserts at the outer high-tension terminals. The ventilation is accomplished by connecting two tubes to the distributor: one leading to the air cleaner (from which clean air can be obtained) and the other to the intake manifold. The intake manifold vacuum causes air to pass through the distributor from the air cleaner, thus keeping the distributor well ventilated. The various leads in the ignition system are enclosed in a watertight conduit. This conduit prevents moisture from getting to the leads with resultant insulation deterioration. The conduit also prevents shorting or grounding caused by presence of water.

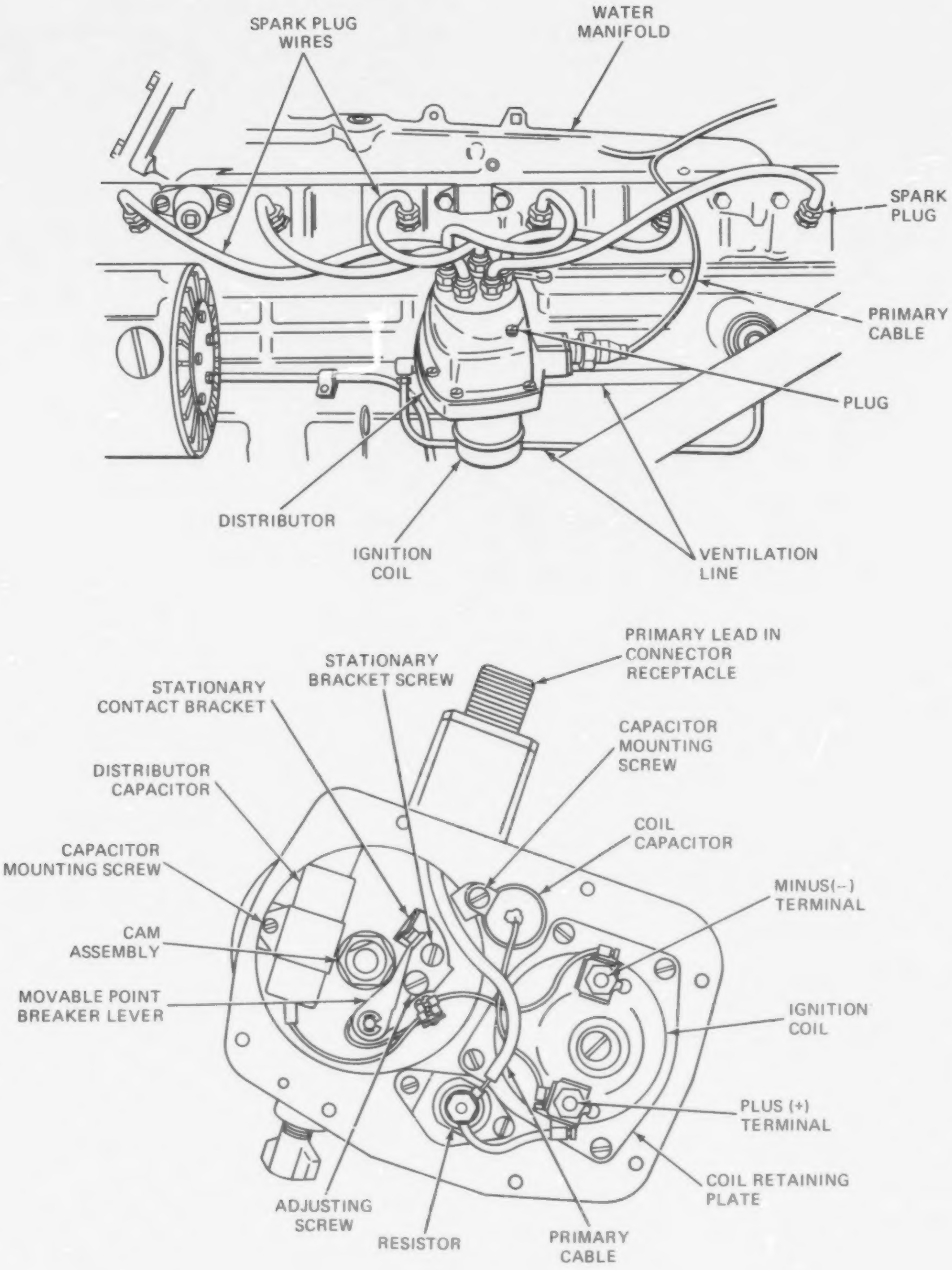

SPARK PLUG WIRES
WATER MANIFOLD
SPARK PLUG
PRIMARY CABLE
PLUG
DISTRIBUTOR
IGNITION COIL
VENTILATION LINE
PRIMARY LEAD IN CONNECTOR RECEPTACLE
STATIONARY BRACKET SCREW
STATIONARY CONTACT BRACKET
CAPACITOR MOUNTING SCREW
DISTRIBUTOR CAPACITOR
COIL CAPACITOR
CAPACITOR MOUNTING SCREW
MINUS(–) TERMINAL
CAM ASSEMBLY
MOVABLE POINT BREAKER LEVER
IGNITION COIL
PLUS (+) TERMINAL
COIL RETAINING PLATE
ADJUSTING SCREW
RESISTOR
PRIMARY CABLE

Figure 15-25. Waterproof Ignition System.

TA233606

CHAPTER 16

LIGHTING SYSTEMS

Section I. MOTOR VEHICLE LIGHTING

16-1. General (Fig. 16-1). The history of motor vehicle lighting parallels the history of the lighting of houses and buildings, with oil lamps and gas lamps having been used in the early motor vehicles. With the development of a satisfactory electrical system, electric lighting has become the standard means of lighting motor vehicles. The lighting system found on most modern motor vehicles consists of the following:

a. Two headlights for illuminating the road ahead of the vehicle.

b. Two parking, or side, lights for indicating the location of the vehicle when parked.

c. Taillights to light the rear license plate and to show a red light to the rear.

d. Instrument panel lights to illuminate the instruments.

e. Body lights, such as dome and step lights, to light the interior of the vehicle.

f. Special lights, such as spotlights, signal lights, blackout lights, and stop and backing lights.

g. Wires and control switches to connect these lights and lamps to the current source.

16-2. Lamps.

a. General Description (Fig. 16-2). Small gas-filled incandescent lamps with tungsten filaments are used on motor vehicles. The filaments supply the light when sufficient current is flowing through them. The lamps are designed to operate at low voltage, such as 6, 12, or 24 volts.

b. Construction (Fig. 16-2). Most lamps are provided with a single contact for each filament within the lamp, the current through each filament being completed to the shell of the lamp base. A double filament lamp with the single-contact construction is shown in figure 16-2. Two contacts are provided on the lamp base, each being connected with one of the filaments. The return from both filaments is to the lamp base shell, which is grounded through the lamp socket. Thus, there are two separate circuits with two contacts on the base, each of which might properly be termed a single contact, for a

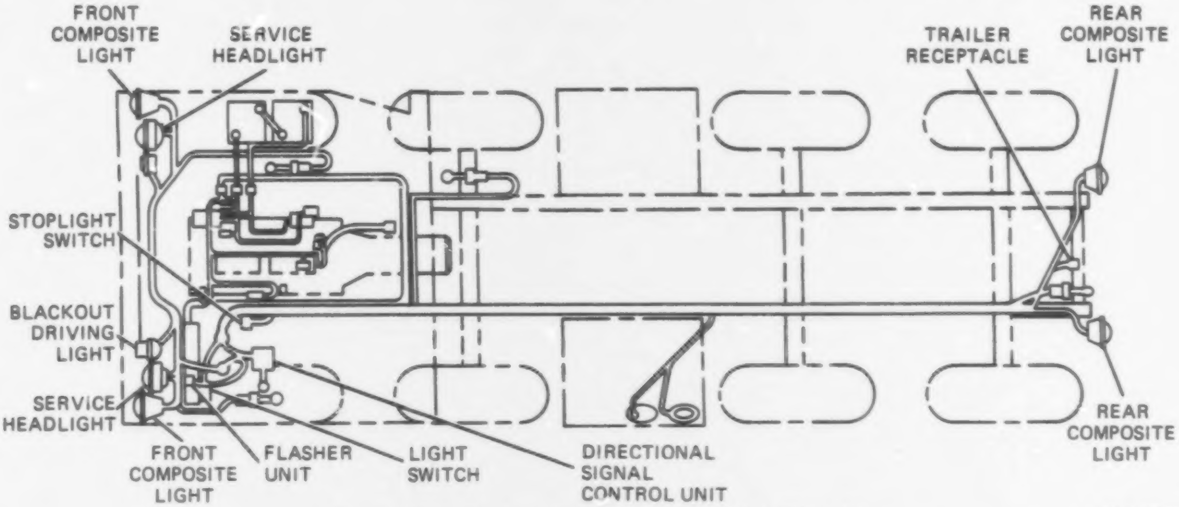

FRONT COMPOSITE LIGHT
SERVICE HEADLIGHT
TRAILER RECEPTACLE
REAR COMPOSITE LIGHT
STOPLIGHT SWITCH
BLACKOUT DRIVING LIGHT
SERVICE HEADLIGHT
REAR COMPOSITE LIGHT
FRONT COMPOSITE LIGHT
FLASHER UNIT
LIGHT SWITCH
DIRECTIONAL SIGNAL CONTROL UNIT

Figure 16-1. Typical Automotive Lighting Circuit.

TA233607

336

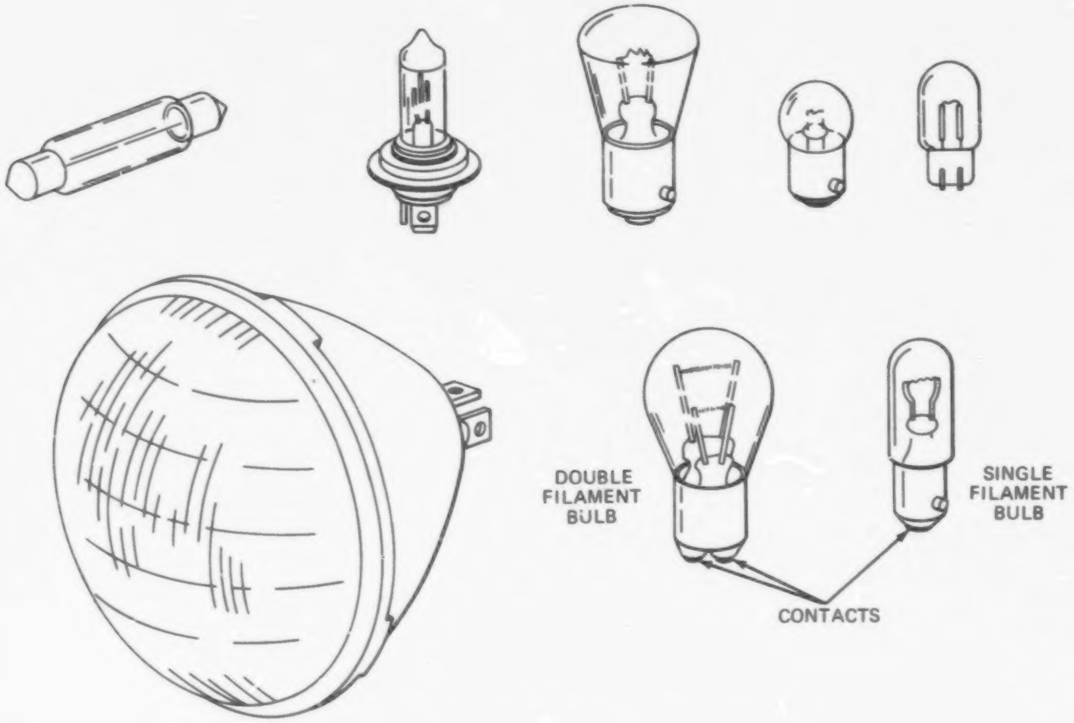


Figure 16-2. Lamp Construction and Configurations.

grounded circuit. Because the voltage used in automotive electrical systems is low and the current required as a result is high, the filaments are much shorter and stronger than those used for standard house lighting lamps. A short and thick, rather than a long and thin, filament can withstand rough treatment, and this is desirable in the case of a lamp subjected to the vibrations of a motor vehicle. A short filament also provides a concentrated light source that will give a better focus.

c. Size (Fig. 16-2). Lamps range in size from the small one-half candlepower instrument panel lamps to the large 50 or more candlepower driving lamps.

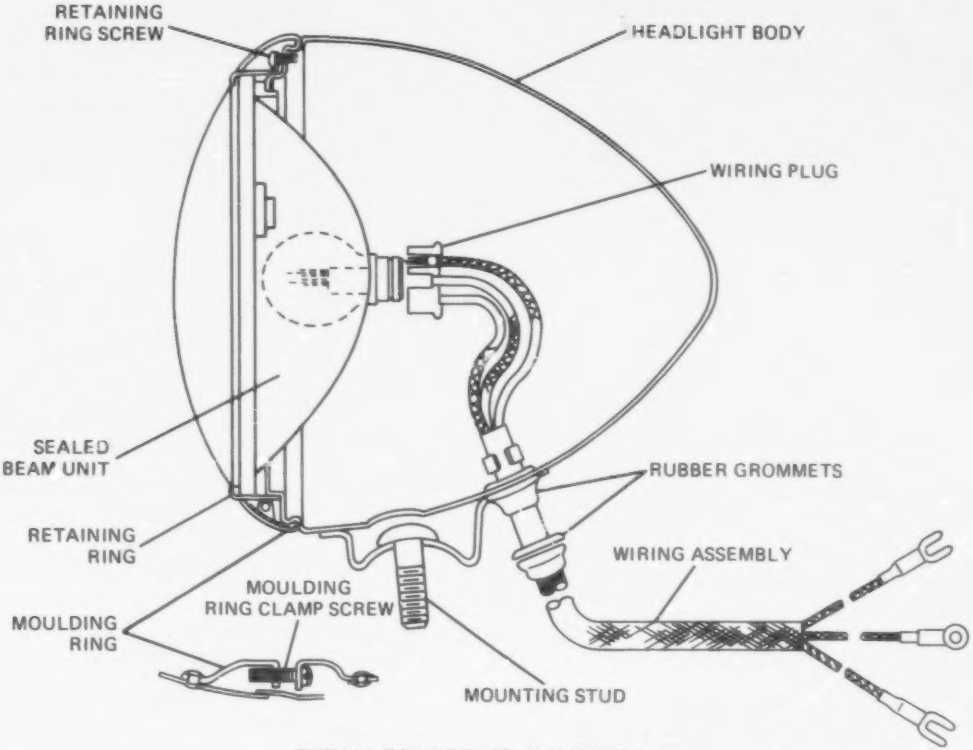
d. Current Requirements. The 2-candlepower lamp consumes 0.21 ampere at 12 volts. The 4-candlepower lamp consumes 0.22 ampere at 12 volts. A lamp similar to the one shown in figure 16-5, having two filaments, one of 32 candlepower and the other of 21 candlepower, will draw 1.3 and 1.8 amperes. One reason for the rapid discharge of storage batteries in winter is the increased number of hours that lamps are used. There is a direct relation between the total current use and the number of lamps used. All storage batteries are rated by ampere-hours; that is, the number of hours a battery can be used at a certain discharge amperage before it becomes depleted. For instance, two headlight lamps burning at 4 amperes each, a total of 8 amperes, would discharge a storage battery rated at 80 ampere-hours in approximately 10 hours, unless the generator charged the battery.

16-3. Light Beams (Fig. 16-3).

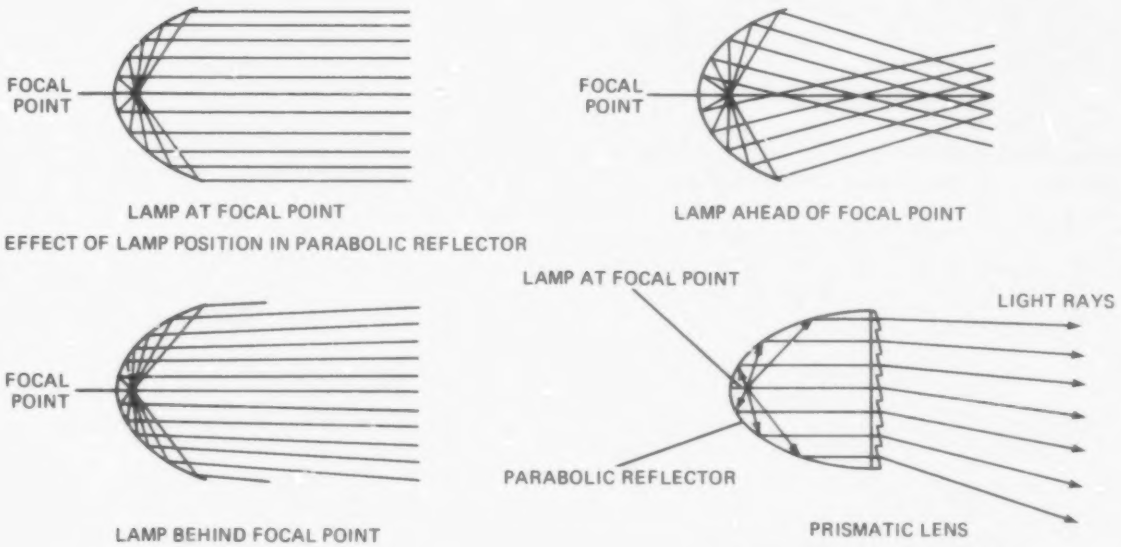
a. Use of Reflector. A lamp bulb is mounted within a reflector so that the light can be gathered and directed in a confined beam. The best light beam from a lamp is obtained by the use of a parabolic or bowl-shaped reflector, which is the type in general use. There is a focal point near the rear of the parabolic reflector at which the light rays from the lamp are picked up by the polished surface of the reflector and directed in parallel lines to give a beam with a circular cross section. Any other position of the lamp will not give as limited a beam, but will tend to scatter the light.

TA233608

837


RETAINING RING SCREW
HEADLIGHT BODY
WIRING PLUG
SEALED BEAM UNIT
RUBBER GROMMETS
RETAINING RING
WIRING ASSEMBLY
MOULDING RING CLAMP SCREW
MOULDING RING
MOUNTING STUD

TYPICAL FOCUSED LIGHT ASSEMBLY


FOCAL POINT
FOCAL POINT
FOCAL POINT
LAMP AT FOCAL POINT
LIGHT RAYS
PARABOLIC REFLECTOR
PRISMATIC LENS

LAMP AT FOCAL POINT

LAMP AHEAD OF FOCAL POINT

EFFECT OF LAMP POSITION IN PARABOLIC REFLECTOR

LAMP BEHIND FOCAL POINT

DISTRIBUTION OF LIGHT RAYS BY PRISMATIC LENS

Figure 16-3. Focused Light Beam Construction.

TA233609

338

BEST COPY AVAILABLE

b. Use of Prismatic Lens. The light beam is distributed over the road by means of a prismatic lens. The effect of a prismatic lens fitted to a parabolic reflector is shown in figure 16-3. The lens bends the paralled rays from the reflector so that the light is distributed over the road. The vertical flutes of the lens spread the light rays so that the beam is flattened, with the edges thrown out toward the side of the highway.

c. Combinations of Beams. Many combinations of light beams are possible. One combination of headlight beams that has been used commonly is shown in figure 16-4. The beam from the right headlight is projected high to the right side of the road and low to the left side, and the beam from the left headlight is projected high to the left side and low to the right side. Portions of the beam are deflected lower than other portions because of the design of the lens. When the right and left beams are not the same, the lenses for right and left headlights are not interchangeable. These beams combine to give a nearly symmetrical beam for driving. With some headlights, the left light illuminates the right side of the road, while the right light illuminates the left side of the road. Both lights together give a symmetrical beam.

16-4. Headlights.

a. General (Fig. 16-5).

(1) In headlights of the older type, means are provided for focusing and directing the light. Focusing means bringing the filament of the lamp to the focal point of the reflector; aiming means pointing or directing the light properly.

(2) Later developments brought into general use a 2-filament lamp having its position fixed with respect to its mounting socket at the rear of the reflector so that the filaments remain fixed at the proper focus (fig. 16-5). It is necessary only to direct the light to improve the lighting of the roadway.

(3) The most common headlamp configuration in modern automotive use is the sealed beam.

b. Sealed Beam (Fig. 16-6).

(1) A superior headlight that has been adopted is the sealed-beam headlamp unit. Not only does it provide far better and more powerful illumination than previous lamps, but it maintains its initial brilliancy with only a slight loss throughout its life. This is because the lens is permanently sealed to the reflector, barring moisture (which corrodes the reflector) and preventing the entrance of dust and dirt.

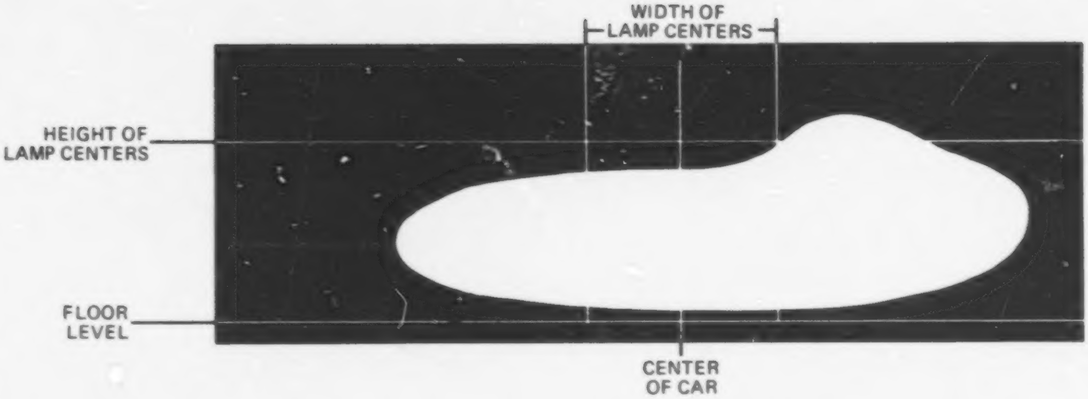
(2) When a filament burns out, the whole unit must be replaced. However, it has a greater filament life than other types of lamps and requires no maintenance to keep it in good condition.

(3) The sealed-beam headlamp unit is made in two types: one with a silver-plated metal reflector and the other with an aluminum-surfaced glass reflector. The metal type contains a conventional double-filament lamp that is sealed in the unit mechanically, whereas the glass type is its own lamp because the lens and reflector are fused together, forming a gastight unit with the filaments sealed into the reflector.

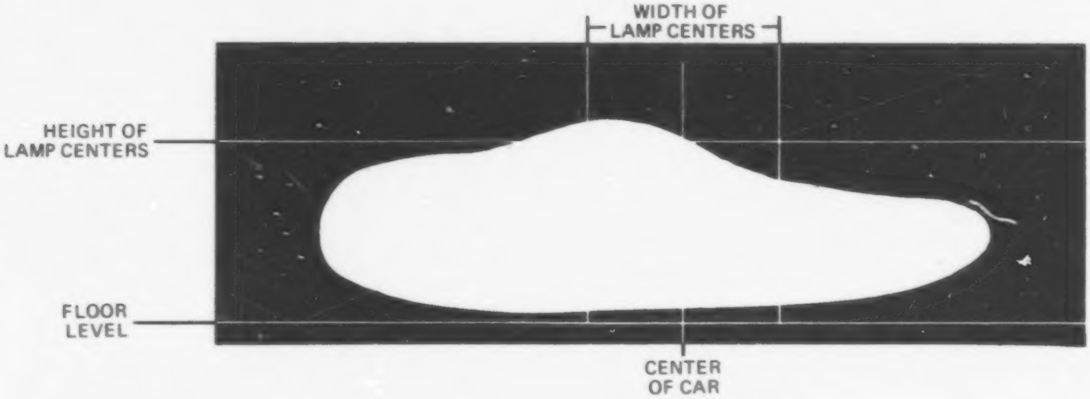
(4) Two filaments are provided in the sealed-beam headlight lamp unit: one provides an upper beam for country driving, and the other gives a downward beam for passing or city driving. With the upper beam in use, current sealed-beam lamp units provide 50 percent more light than previous 32-candlepower lamps, and also distribute the light more effectively. The upper beam filament requires 40 to 45 watts, and the depressed beam filament requires 30 to 35 watts, which is more current than that required by the 32-candlepower lamps. Directing the headlight to the roadway is the only adjustment required on sealed-beam headlamps.

(5) The sealed-beam headlamp is mounted with long self-locking screws and springs. The screws serve to aim the headlamps, depending on their position.

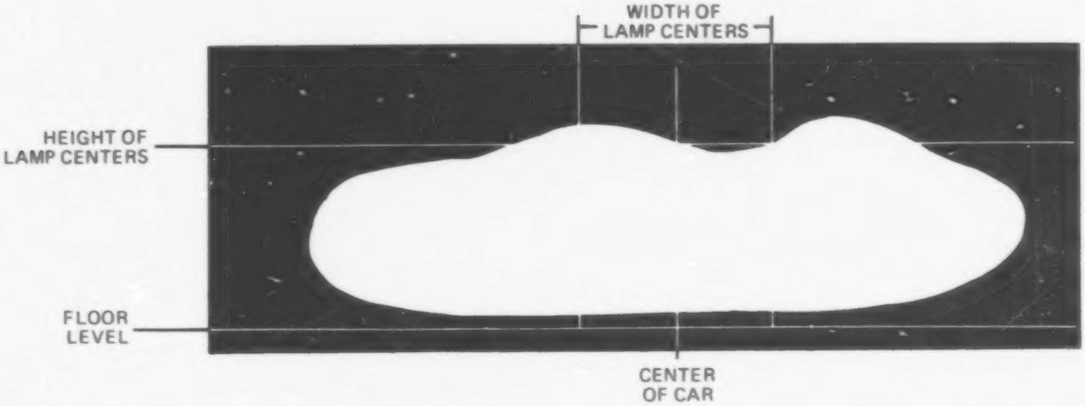
16-5. Road Illumination (Fig. 16-4). Modern development has brought about a radical change in what is considered good road illumination. The high-intensity beam of light has given way to the principle of more illumination and lower general


WIDTH OF LAMP CENTERS
HEIGHT OF LAMP CENTERS
FLOOR LEVEL
CENTER OF CAR

RIGHT HEADLAMP


WIDTH OF LAMP CENTERS
HEIGHT OF LAMP CENTERS
FLOOR LEVEL
CENTER OF CAR

LEFT HEADLAMP


WIDTH OF LAMP CENTERS
HEIGHT OF LAMP CENTERS
FLOOR LEVEL
CENTER OF CAR

RIGHT AND LEFT HEADLAMPS COMBINED

Figure 16-4. Automotive Headlamp Pattern.

TA233610

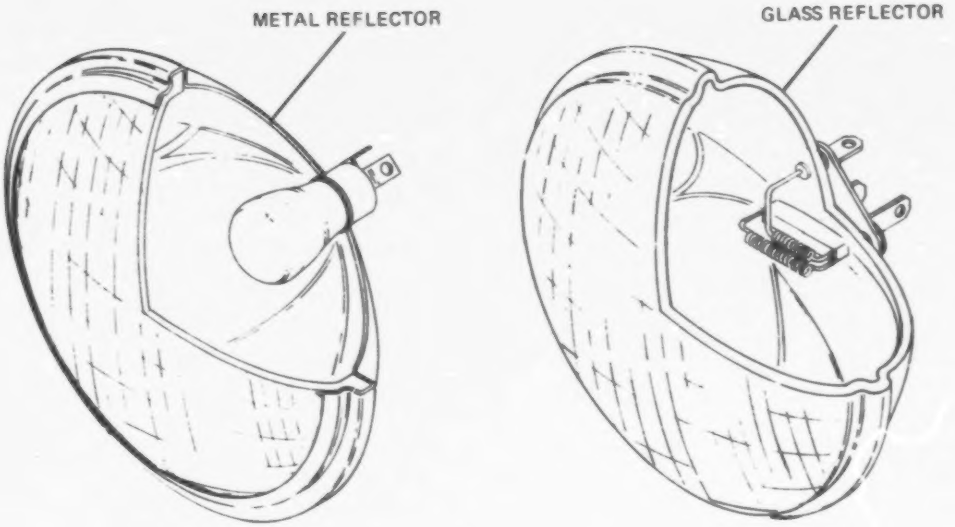


Figure 16-5. Automotive Headlamp Configurations.

intensity. The 32-candlepower lamp is sufficient with a narrow, high-intensity beam, but with the general floodlighting effect desired today, a larger light source is necessary. The sealed-beam headlamp has been developed to meet these requirements. With the increased use of high-powered lamps have come laws enforcing the proper focusing of the lights and the use of dual-beam headlamps. The dual-beam headlamp is designed so that one filament will be at the focal point of the reflector, and the other filament will be out of focus slightly so that the rays will be turned downward. Depressing the beam is accomplished by a switch that changes the current from one filament to the other.

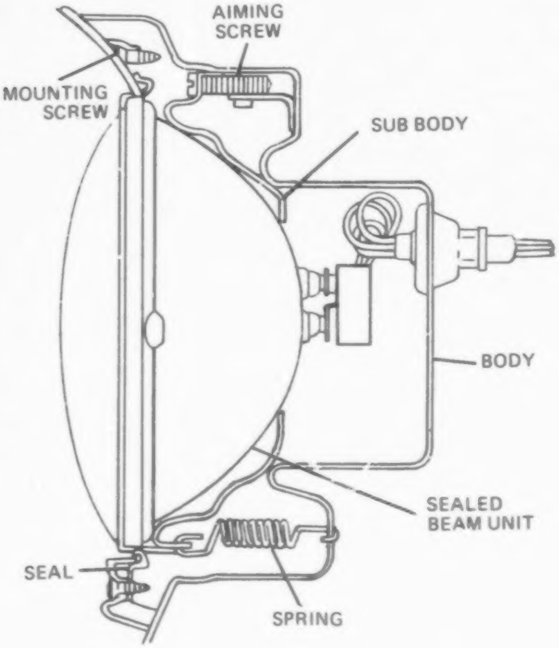


Figure 16-6. Sealed-Beam Headlamp Construction.

16-6. Elimination of Glare.

a. Cause of Glare. Any light source is said to produce glare if it reduces the clarity of vision of anyone looking toward it. Practically speaking, the blinding or dazzling effect of light is not due to the brilliancy of the light but to the lack of illumination in the immediate vicinity through which the rays are projected. The headlight, for example, that produces glare on a dark road at night would not produce glare on a well-lighted street, and in the daytime with the sun shining, it would hardly be noticed. If the strong light rays can be kept below the eye level, the nuisance of glare will be eliminated.

b. Elimination. Many tests have been conducted by the Society of Automotive Engineers and by manufacturers to eliminate headlight glare as much as possible and still have enough light for safe driving. Two beams are specified to meet

TA233611

these requirements: an upper beam to provide enough light in front of the vehicle while driving, and a depressed beam to avoid dangerous glare under normal conditions of passing. The driver is responsible for selecting the proper beam. The maximum and minimum intensity at important points of both beams are definitely specified and can be checked with the light intensity or foot-candle meter.

16-7. Headlamp Control Systems. Two headlamp controls usually are provided: one to turn them on and off, and the other to select between the upper and the depressed beams.

a. *Control Switch.* The control switch is usually a master-type switch controlling the head, tail, parking, and instrument lights.

(1) One type of headlight switch is a push-pull type that mounts on the instrument panel (fig. 16-7). When the switch is pulled outward it will have two on positions. The first on position will turn on the tail and parking lights. Pulling the switch out to the second on position will turn on the headlights in addition to the lights turned on at the first on position. This type of switch also has a control rheostat built into it to control the intensity of the instrument lamps. The rheostat is controlled by turning the knob.

(2) The current trend in the design of headlight switches integrate them with the turn signal switch (fig. 16-8). The switch usually is controlled by a knob at the end of the turn signal lever. The turning of the knob to the first on position turns on the tail, park, and instrument lamps. Moving it to the second position also will turn on the headlights. With this switch configuration, the intensity of the instrument lamps usually is controlled by a separate rheostat that is mounted on the instrument panel.

(3) Military vehicles that are used in tactical situations are equipped with a headlight switch that is integrated with the blackout lighting switch (fig. 16-9). An important feature of this switch is that it reduces the possibilty of accidentally turning on the lights in a blackout. With the main switch off, no lights are on. It can be turned to the left, without operating the mechanical switch, to get blackout marker lights (including blackout

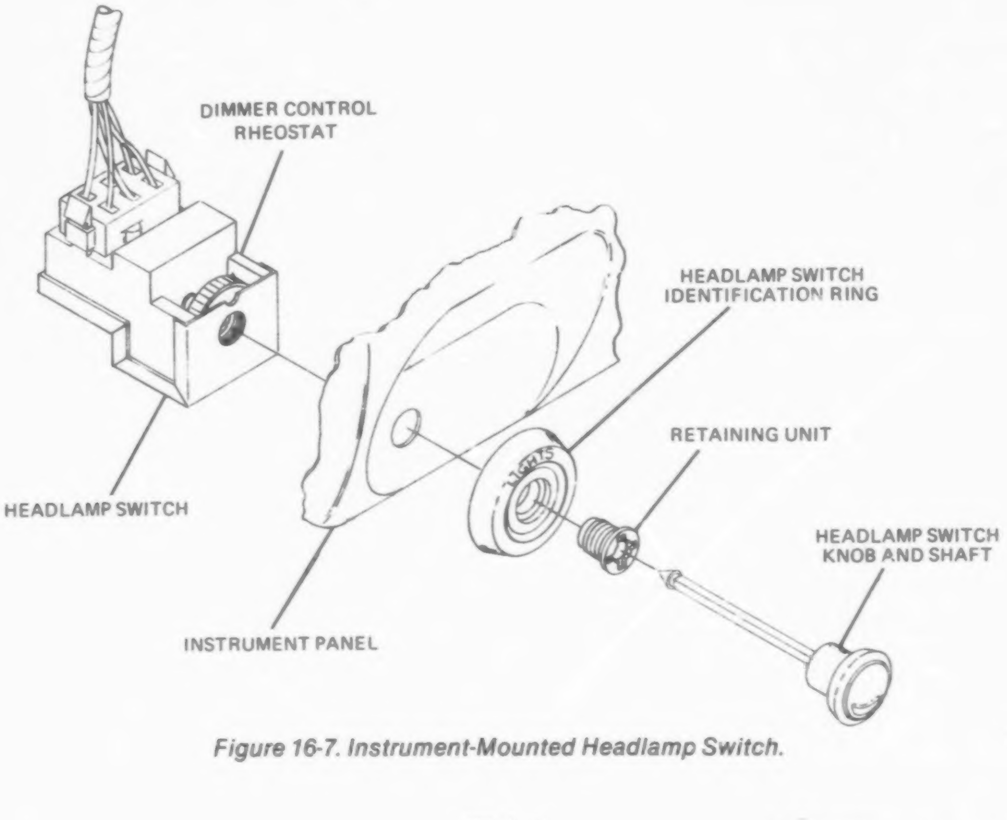


Figure 16-7. Instrument-Mounted Headlamp Switch.

TA233612

342

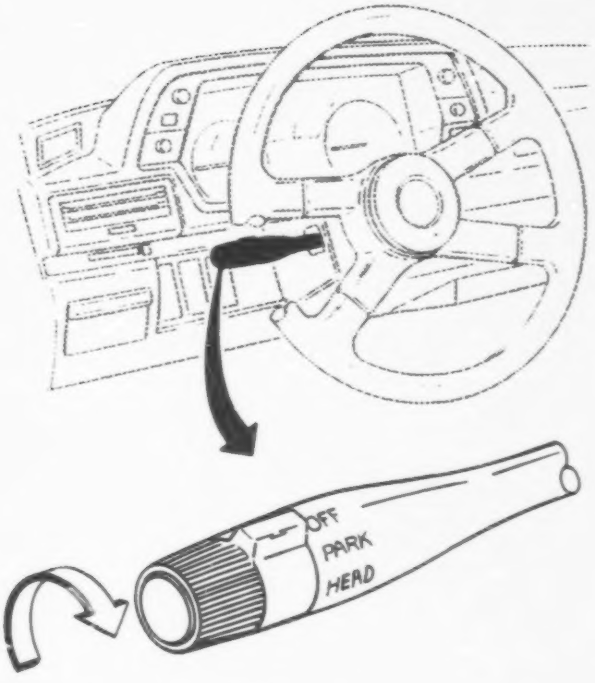


Figure 16-8. Turn Signal Lever-Mounted Headlamp Switch.

taillights and stop lights), and blackout driving lights. But for stop lights for daylight driving, or normal bright lights for ordinary night driving, you must first lift the mechanical switch lever and then turn the main switch lever to the right. The auxiliary switch gives panel lights when the main switch is in any of its ON positions. But it will give parking lights only when the main switch is in service drive (to the extreme right). When the main switch is off, the auxiliary switch should not be moved from the OFF position.

b. Dimmer Switch. The dimmer switch is used to control solely the selection of headlamp beams. The main consideration in locating the headlamp switch is the ease of finding it by the driver without diverting attention from vehicle operation.

(1) One of the most common locations for the dimmer switch is on the floor to the left of all of the control pedals (fig. 16-10). This switch configuration uses a single metallic button that alternately selects between headlamp beams each time it is depressed.

(2) Currently, the most popular dimmer switch configuration is integrated in the turn signal lever (fig. 16-11). The operator selects the desired headlamp beam by moving the lever towards the front or rear. If this dimmer switch configuration is used with a headlamp switch that is also integrated in the turn signal lever, then the two switches and the turn signal switch usually are serviced as one unit.

16-8. Overload Breakers. Besides limiting the current by current regulation, the battery and wiring should be protected against excessive loads that might occur due to shorts or grounds in the wiring system. This protection may be secured by a current-limiting circuit breaker or a single fuse. The location of an overload breaker in the electrical system is shown in figure 16-12.

a. Circuit Breaker (Fig. 16-13).

(1) The circuit breaker is a protective device designed to open the circuit when excessive current passes through its windings. All current for lights and accessories pass through the circuit breaker. It is similar in construction to the cutout, but opens the circuit rather than closes it. If there is a ground or other trouble in the circuit, the rush of current will start the circuit breaker vibrating and in this way it indicates that there is something wrong in the system. The device breaks the circuit at about 25 amperes but, after opening, allows only about 5 amperes to pass through, which keeps it vibrating. Thus the circuit breaker protects the battery from rapid discharge when trouble develops. The circuit breaker will continue to vibrate until the trouble is found and corrected.

(2) In all types of circuit breakers, the short circuit must be removed before the breaker can be reset. The short circuit can be located easily by disconnecting each circuit separately until the circuit breaker stops vibrating.

(3) Some automatic breakers do not vibrate, but have a telltale light placed across the contacts. This light, generally placed where it is visible to the operator, is protected by a resistance. When the circuit breaker contacts are opened by excessive current, the light flashes on. There is generally sufficient current flowing through the relay coil with the lamp in series to

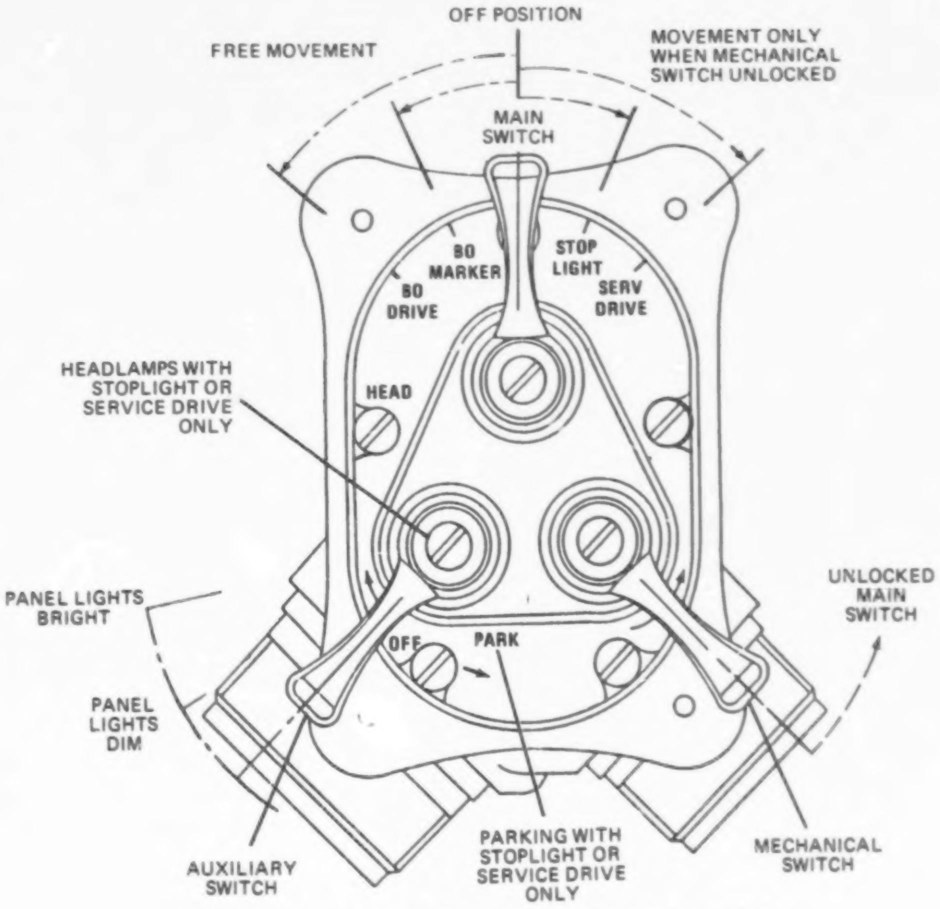

OFF POSITION
FREE MOVEMENT
MOVEMENT ONLY WHEN MECHANICAL SWITCH UNLOCKED
MAIN SWITCH
BO MARKER
STOP LIGHT
BO DRIVE
SERV DRIVE
HEADLAMPS WITH STOPLIGHT OR SERVICE DRIVE ONLY
HEAD
PANEL LIGHTS BRIGHT
UNLOCKED MAIN SWITCH
OFF
PARK
PANEL LIGHTS DIM
AUXILIARY SWITCH
PARKING WITH STOPLIGHT OR SERVICE DRIVE ONLY
MECHANICAL SWITCH

Figure 16-9. Blackout Light/Headlamp Switch.

hold the contact arm of the circuit breaker down until the short is removed. After removing the short, it may be necessary to turn off all lights for an instant to permit the relay to reset itself and extinguish the telltale light.

b. Fuse (Fig. 16-14). A common method of protection is to use a fuse in the lighting circuit. Whenever there is an excessive current through the lighting circuit, the fuse will burn out and open the circuit. The short circuit should be removed before the fuse is replaced. The disadvantages of using a fuse are that the circuit must be traced to locate the trouble and that a burned-out fuse must be replaced. However, it provides much cheaper protection to the system.

TA233614

344

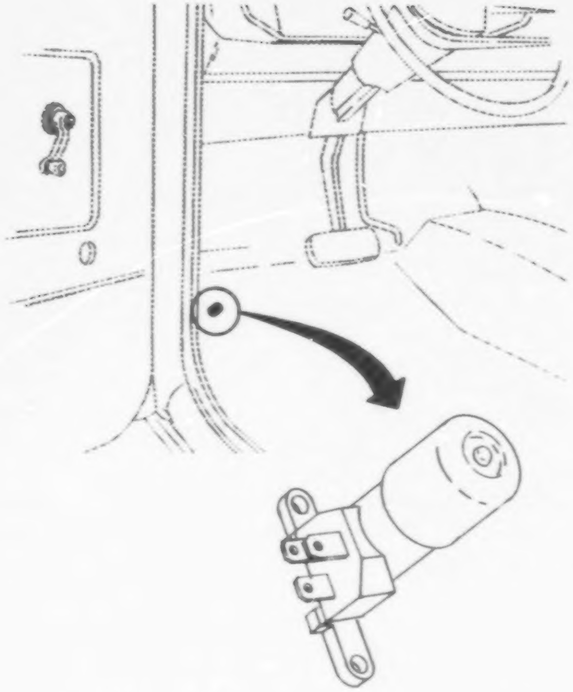


Figure 16-10. Floor-Mounted Dimmer Switch.

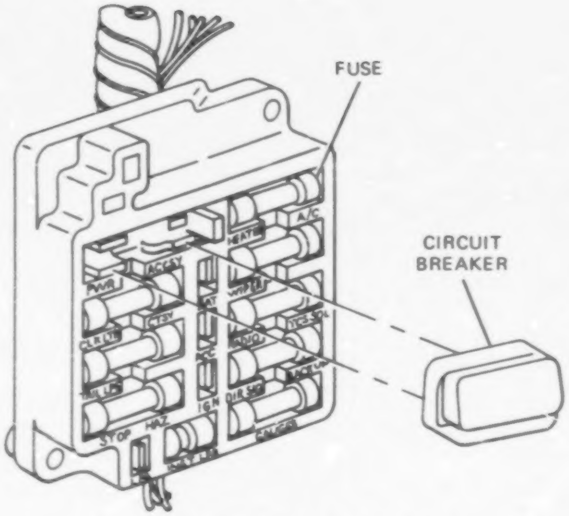

FUSE
CIRCUIT BREAKER
A/C
IGN
STOP
HAZ

Figure 16-12. Overload Breakers.

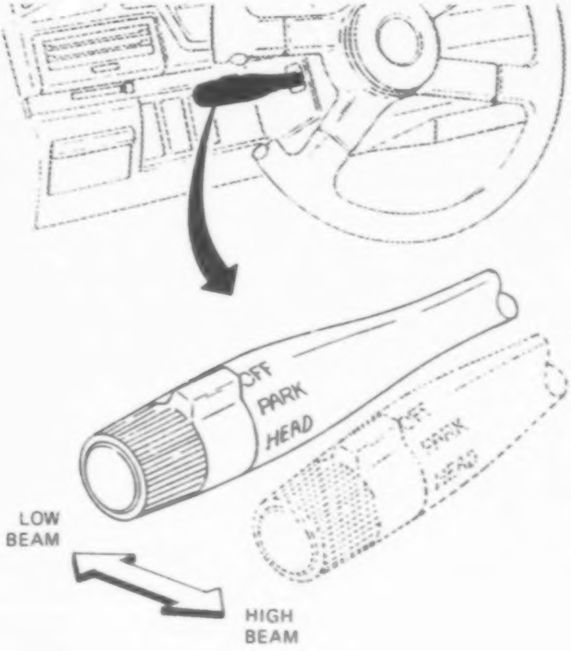

OFF
PARK
HEAD
LOW BEAM
HIGH BEAM

Figure 16-11. Turn Signal Lever-Mounted Dimmer Switch.

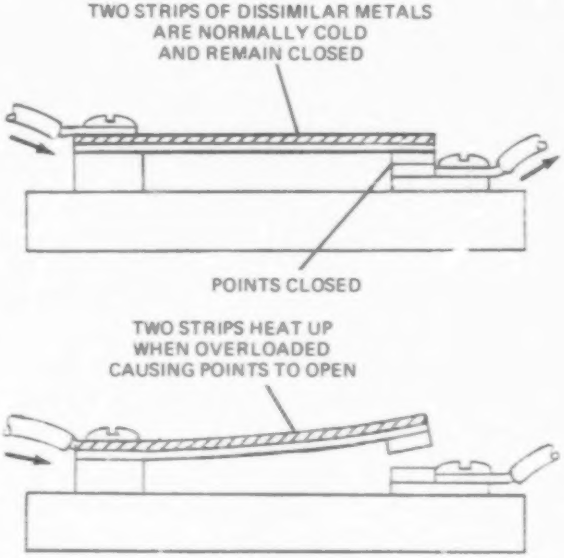

TWO STRIPS OF DISSIMILAR METALS ARE NORMALLY COLD AND REMAIN CLOSED
POINTS CLOSED
TWO STRIPS HEAT UP WHEN OVERLOADED CAUSING POINTS TO OPEN

Figure 16-13. Demonstration of Circuit Breaker Operation.

TA233615

345

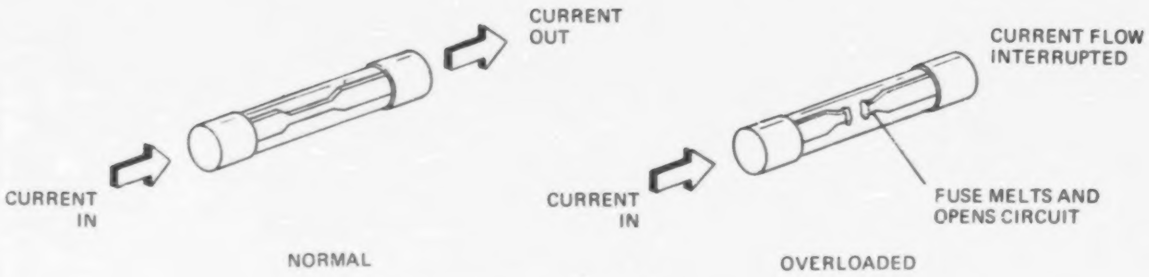


Figure 16-14. Demonstration of Fuse Operation.

Section II. BLACKOUT LIGHTING

16-9. Purpose. Blackout lighting is a requirement for certain combat operations. One purpose of blackout lighting is to provide the vehicle operator with sufficient light to operate the vehicle in total darkness. Another is to provide minimum lighting to show vehicle position to a leading or trailing vehicle when the illumination must be restricted to a level not visible to a distant enemy.

16-10. Configurations.

a. The blackout driving light (fig. 16-15) is designed to provide a white light of 25 to 50 candlepower at a distance of 10 feet directly in front of the lamp. The lamp is shielded so that the top of the light beam is directed not less than 2 degrees below the horizon. The beam distribution on a level road at 100 feet from the lamp is 30 feet wide on a properly designed light.

b. The blackout stoplight, marker light (fig. 16-16), and taillight are designed to be visible at a horizontal distance of 800 feet and not visible beyond 1200 feet. The lights also must be invisible from the air above 400 feet with the vehicle on upgrades and downgrades of 20 percent. The horizontal beam cutoff for the lights is 60 degrees right and left of the beam centerline at 100 feet.

c. The composite light (fig. 16-17) is currently the standard lighting unit that is used on the rear of tactical military vehicles. The composite light combines service stop, tail, and turn signals with blackout stop and tail lighting.

16-11. Controls and Lockouts. Blackout lighting control switches are designed to prevent the service lighting from being turned on accidentally. Their operation is described in paragraph 16-7a (3).

16-12. Infrared Lighting. Infrared (ir) lighting provides vision to troops at night, like blackout lighting. Unlike blackout lighting, however, ir lighting is undetectable to the human eye. There are two basic types of ir lighting systems: the active system and the passive system.

a. Active System. The active system uses a light source combined with a red lens to emit light in the near ir range. The emitted light is reflected back from the illuminated object and focused in an image-converter tube. The tube converts an image formed in one wavelength of radiation into an image in a visible wavelength for viewing. The tube contains both the sensor and display in one unit. The ir lighting system employed on present

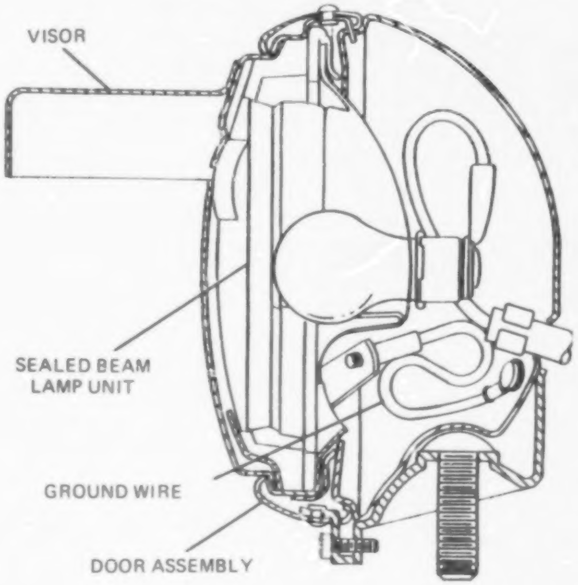


Figure 16-15. Blackout Driving Light.

TA233616

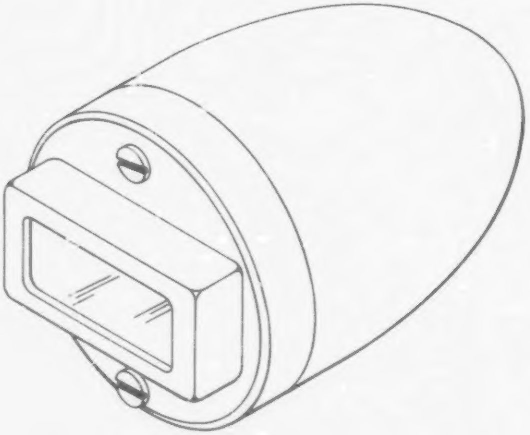


Figure 16-16. Blackout Stop and Marker Light.

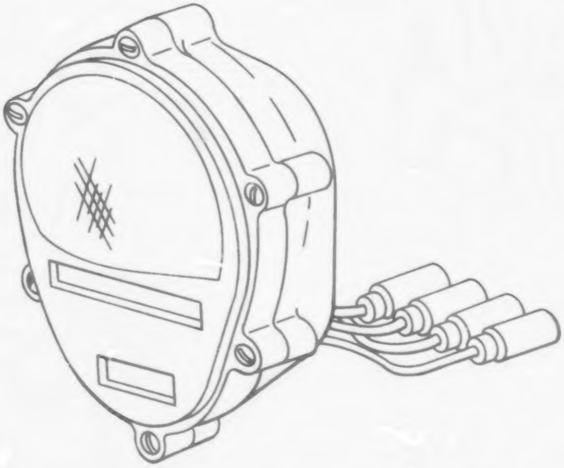


Figure 16-17. Military Composite Light.

tank-automotive vehicles is of this type. The active ir system has the disadvantage of being detectable by an enemy equipped with ir detectors operating in the same range. For this reason, the active ir equipment is expected to be phased out completely and replaced by passive systems.

b. Passive System. A passive ir system cannot be detected or disabled by methods that are effective against active systems. Furthermore, most natural objects radiate in the ir region, making a passive system very attractive. There are basically two types of passive ir systems: light intensification, and far-infrared.

(1) Light intensification systems are expected to eventually replace the present active ir systems for tank-automotive applications. In the light intensification system, images formed by the ambient light from starlight or moonlight are intensified by image converter-type tubes. The image converter tubes have a high detective photo-cathode sensitivity in the visible and in the near-infrared region. The light intensification system is characterized usually by its relatively small size and is less complex than active systems because of the elimination of transmitting hardware. The major disadvantage of this system is that, like normal viewing, range and performance depend on atmospheric conditions.

(2) The far-infrared ir systems operate by utilizing light wavelengths that operate at the far end of the infrared spectrum. Wavelengths in this region are transmitted fairly well by the atmosphere, except in extreme humidity or rain. These systems utilize the natural radiation from a given object to provide the power by which the object is detected. Systems of this type can be highly sensitive and have been designed to detect even the shadow left by an object removed from its surroundings. These are receiving much attention in target location systems. A disadvantage at the present time is the large size of the equipment compared to the light intensity systems.

Section III. COMMERCIAL VEHICLE LIGHTING

16-13. Turn Signal System.

a. General. Vehicles that operate on any public roads in the United States must be equipped with turn signals that indicate a left or right turn by providing a flashing light signal at the front and rear of the vehicle.

b. Control Switch (Fig. 16-18). The turn signal switch is located on the steering column. It is designed to be shut off automatically after the turn is completed by the action of the cancelling cam.

c. Switch Wiring and Electrical Operation.

(1) A wiring diagram for a typical turn signal switch is shown in figure 16-19.

TA233617

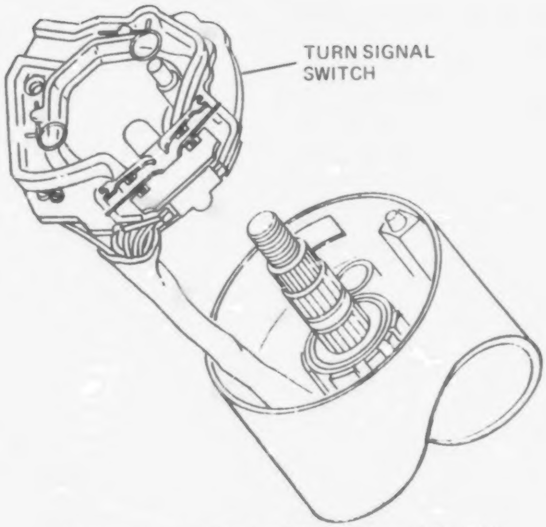


Figure 16-18. Typical Turn Signal Switch.

(2) A common design for a turn signal system is to use the same rear lamps for both the stop and turn signals. This complicates the design of the switch somewhat. Note that the stoplight circuit must pass through the turn signal switch. When the turn signal switch is turned off, it must pass stoplight current to the rear lamps. As a left or right turn signal is selected, the stoplight circuit is opened and the turn signal circuit is closed to the respective rear lamp. Also note that when this circuit is used, the front and instrument lamps must be on a separate switch circuit.

d. Flasher Unit (Fig. 16-20). The turn signal flasher unit creates the flashing of the turn signal lamps. It consists basically of a bimetallic strip (two dissimilar metals bonded together) wrapped in a wire coil. The bimetallic strip serves as one of the contact points.

(1) When the turn signals are actuated, current flows into the flasher, first through the heating coil to the bimetallic strip, then through the contact points and out of the flasher, where the circuit will be completed through the turn signal lamps.

(2) The current flowing through the heating coil will heat the bimetallic strip, causing its dissimilar metals to expand at different rates. This

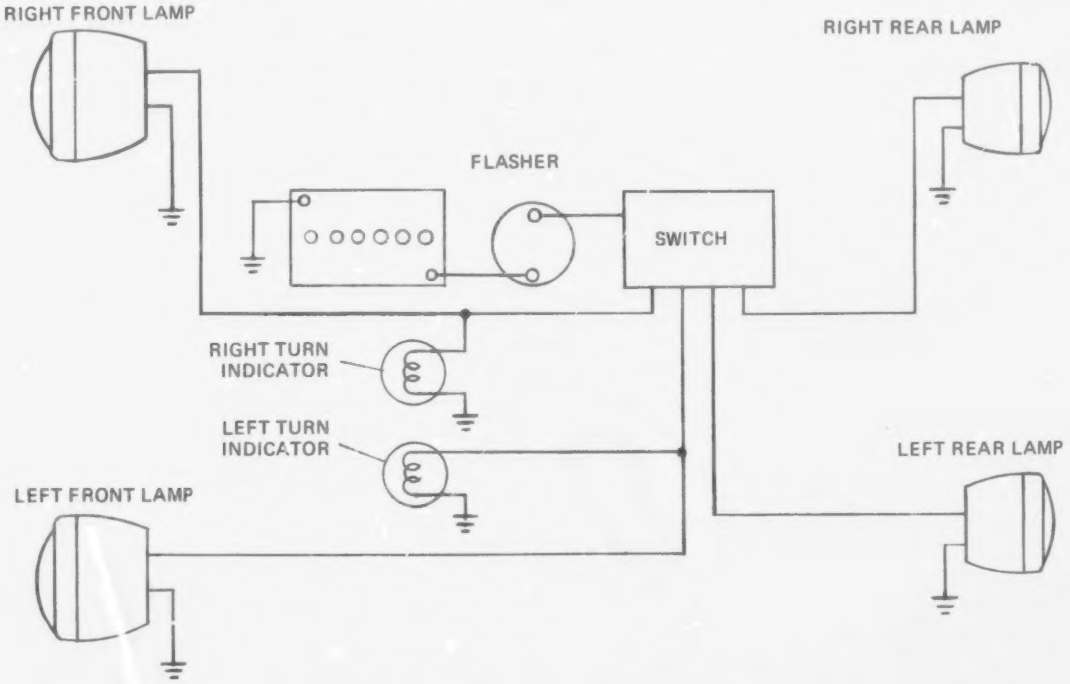


Figure 16-19. Typical Turn Signal Wiring Diagram.

TA233618

348

BEST COPY AVAILABLE

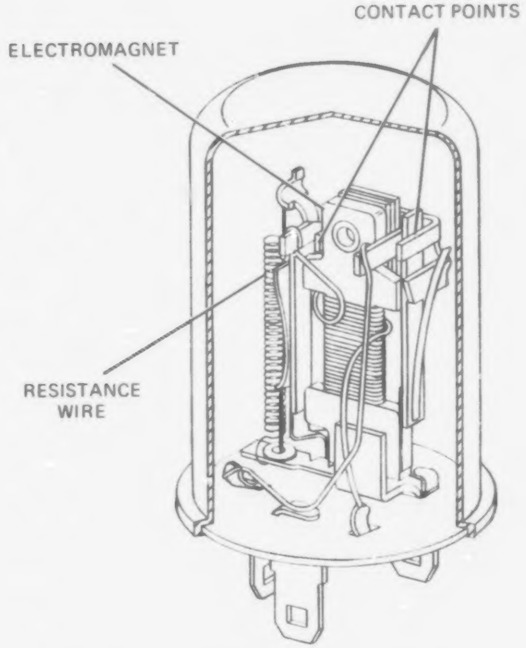


Figure 16-20. Turn Signal Flasher.

movement will close the contact points and cause the flasher to pass full current to the turn signal lamps, lighting them.

(3) The closing of the points causes the current to cease flowing across the heating coil. The cooling of the heating coil in turn will cause the bimetallic strip to contract, pulling the contact points open again. This again will turn off the turn signal lamps.

(4) This sequence of events will repeat a few times a second, causing a steady flashing of the turn signals.

16-14. Backup Light System.

a. General. The backup lamp system provides a warning to pedestrians and visibility to the rear whenever the vehicle is shifted to reverse. A typical backup light system is shown in figure 16-21.

b. Switch Configurations. The most common backup light switch configurations are:

(1) The backup light switch may be mounted on the transmission and operated by the shift linkage.

(2) The backup light switch may be mounted on the steering column and operated by the gearshift linkage.

(3) The transmission or gearshift mounted backup light switch on many automatic transmission-equipped vehicles is combined with the neutral safety switch.

16-15. Stoplight System.

a. General. All vehicles that are used on public highways must be equipped with a stoplight system. The stoplight system consists of one or two red lamps on the rear of the vehicle that light up whenever the brake is applied. Typical stoplight wiring circuits are shown in figure 16-22. It should be noted that some stoplight circuits are integrated in the turn signal circuit. These circuits are described in paragraph 16-13.

b. Stoplight Switch Configurations (Fig. 16-23). Some models have stoplight switches that are actuated mechanically by the brake

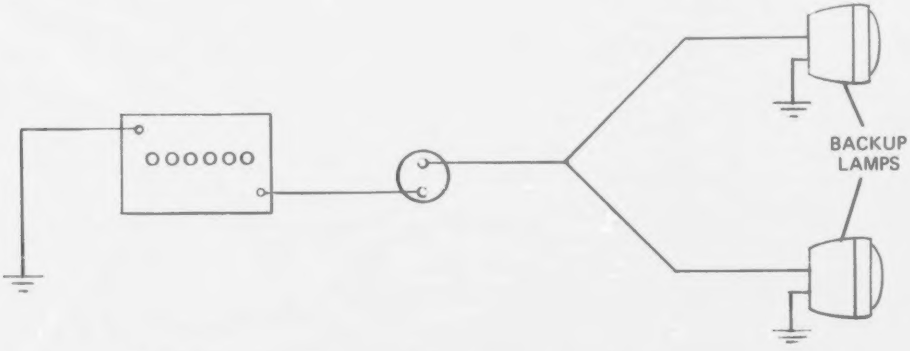
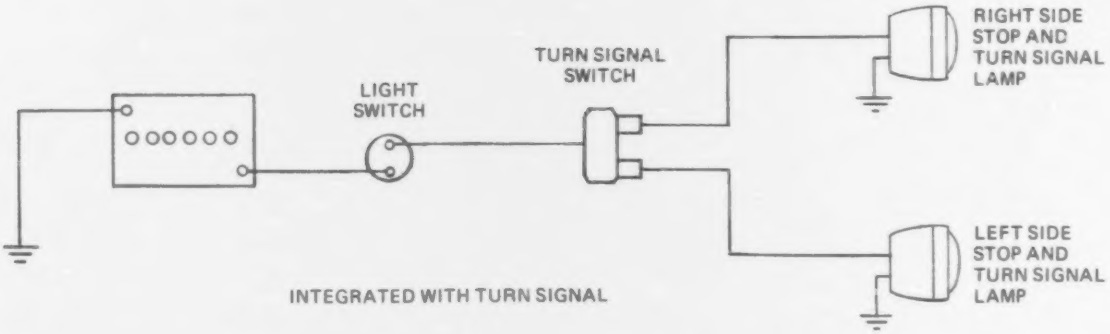
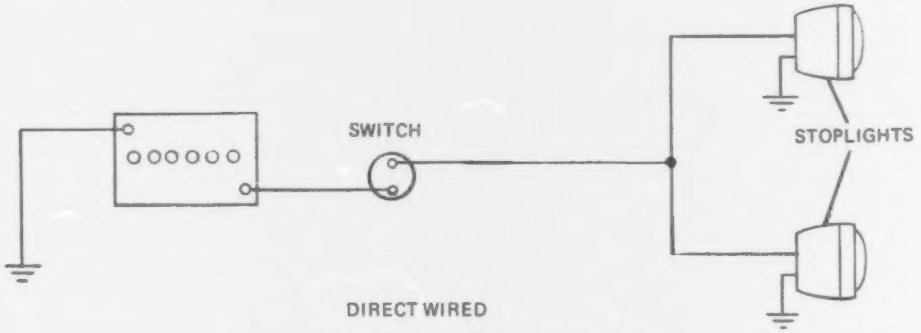


Figure 16-21. Typical Backup Light System.

TA233619


LIGHT SWITCH
TURN SIGNAL SWITCH
RIGHT SIDE STOP AND TURN SIGNAL LAMP
LEFT SIDE STOP AND TURN SIGNAL LAMP

INTEGRATED WITH TURN SIGNAL


SWITCH
STOPLIGHTS

DIRECT WIRED

Figure 16-22. Stoplight Switch Configurations.

pedal. Other models use a switch that is actuated by the hydraulic line pressure.

16-16. Other Lights.

a. Instrument Lights. Ordinarily, indirect lighting is used for the instrument lamps, which light whenever the lighting switch is in any of the ON positions. Many cars are equipped with an instrument panel lamp switch so that the instrument panel lamps can be turned off when desired.

b. Dome Lights. Practically all closed motor vehicles make use of dome or tonneau lights. These ordinarily are controlled by means of a switch on the body post near each door.

c. Parking Lights.

(1) The smaller lights used for parking sometimes are located immediately above or below the main headlights.

(2) Side lights sometimes serve as parking lights, in which case, a separate housing is used.

(3) A smaller lamp, located within the main headlight and above the main headlight lamp, frequently has been used to provide a parking light. A 4- or 6-candlepower lamp, or smaller, is used for a parking light.

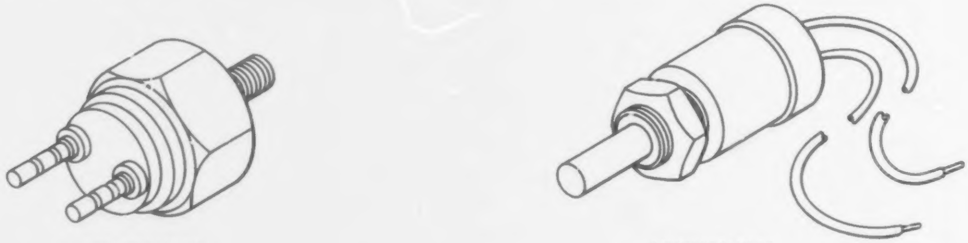

HYDRAULIC
MECHANICAL

Figure 16-23. Typical Stoplight System.

TA233620

CHAPTER 17

INSTRUMENTS, GAGES, AND ACCESSORIES

Section I. INSTRUMENT PANEL

17-1. Purpose (Fig. 17-1). The instrument panel usually is placed so that the instruments may be read easily by the driver. They inform the driver of the approximate speed, engine temperature, oil pressure, rate of charge or discharge of the battery, amount of fuel in the fuel tank, distance traveled, and the time. Certain controls frequently are mounted on the instrument board, such as the throttle, choke, starter, heater, and windshield wiper.

17-2. Battery Condition Gages. One of the instruments that almost always is included on an instrument panel is a battery condition gage. It is a very important indicator because, if interpreted properly, it can be used to troubleshoot or prevent breakdowns. The following are the three basic configurations of battery condition gages.

a. Ammeter (Fig. 17-2). The ammeter is used to indicate the amount of current flowing to and from the battery. It does not give an indication of total generator output because other units in the electrical system, besides the battery, are supplied by the generator. If it shows a 10-ampere discharge, it indicates that a 100 ampere-hour battery would be discharged in 10 hours; that is, 10 amperes flowing for 10 hours. Current flowing from the storage battery to the starting motor is never sent through the ammeter, because the great quantities used (200 to 600 amperes) cannot be measured on an instrument of such limited capacity. In the typical ammeter, all the current flowing to and from the battery, except for starting, actually is sent through a coil to produce a magnetic effect that deflects the ammeter needle in proportion to the amount of current. This coil is matched to the maximum current output of the generator and this varies with different applications. Some model wheeled vehicles have replaced the ammeter with a battery generator indicator that does not give a calibrated reading, but shows ranges by colors or bands.

b. Voltmeter (Fig. 17-3). Voltmeters are gaining popularity as an instrument panel battery condition indicator. This is because the electrical system voltage is a more accurate indication of the condition of the electrical system than the amperage and is easier to interpret by the operator. During vehicle operation, the voltage indicated on the voltmeter is considered to be normal in a range of 13.2 to 14.5 volts for a 12-volt electrical system. As long as the system voltage remains in this range, the operator can assume that no problem exists. This contrasts with an ammeter, which gives the operator no indication of problems such as an improperly calibrated voltage regulator, which could allow the battery to be drained by regulating system voltage to a level that is below normal.

c. Indicator Lamp. The indicator lamp has gained increasing popularity as an electrical system condition gage over the years. Although it does not provide as detailed an analysis of electrical system condition as a gage, it usually is considered more useful to the average vehicle operator. This is because it is highly visible when a malfunction occurs, whereas a gage usually is

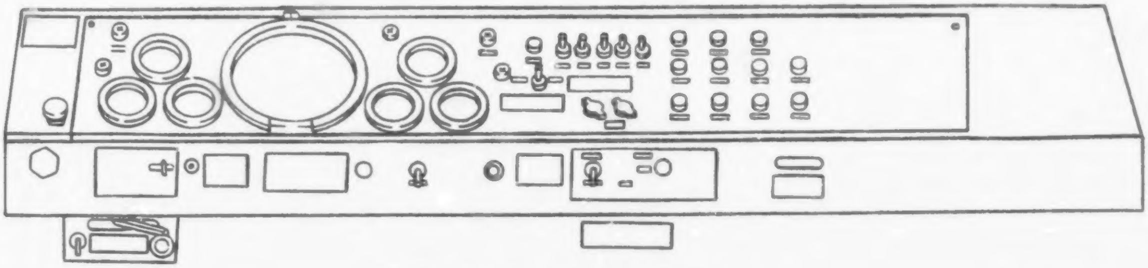


Figure 17-1. Typical Instrument Panel.

TA233621

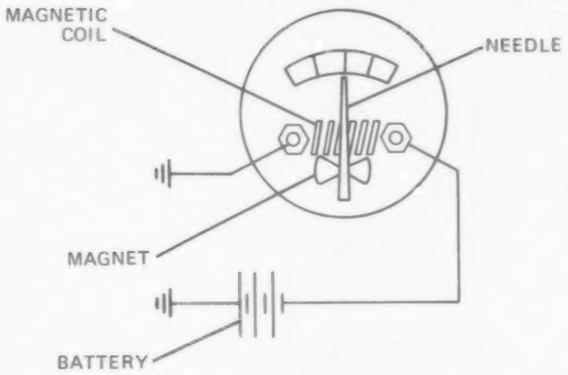


Figure 17-2. Ammeter Operation.

ignored because the average vehicle operator does not know how to interpret its readings. The indicator lamp can be utilized in two different ways to indicate an electrical system malfunction.

(1) *Low-Voltage Warning (Fig. 17-4).* The indicator lamp can be set up to warn the operator whenever the electrical system voltage has dropped below the normal operational range. The lamp is operated by a calibrated relay that opens the circuit to it whenever electrical system voltage is in the normal range (13.2 to 14.5 volts for a 12-volt system). Whenever the voltage falls below the normal range, the magnetic field becomes insufficient to overcome the force of the relay spring, which pulls the contact points closed. This closes the circuit to the indicator lamp.

(2) *No-Charge Indicator (Fig. 17-5).* The indicator lamp also can be set up to indicate whenever the alternator is not producing current. The circuitry that operates a no-charge indicator lamp usually is incorporated in the voltage regulator. The voltage regulator that is used on a vehicle equipped with a no-charge indicator lamp contains a second element called a field relay. The field relay has two contact points. One contact point is connected to battery voltage through the ignition switch. The other point also is connected the same way, except for the inclusion of a series-parallel arrangement of the no-charge indicator light and a resistor. The resistor value is matched with the resistance of the indicator lamp so that their parallel arrangement will produce a zero-voltage drop. When the field relay is open, alternator field current is supplied through the resistor-indicator light combination. The magnetic coil of the field relay is energized directly from the alternator stator through the stator terminal. When the ignition switch is closed, before the engine is started, current flows through the resistor and the indicator lamp to the alternator field, causing the indicator lamp to light. After the engine is started, the alternator begins to produce current, energizing the field relay coil from the stator. The relay coil pulls the relay points closed, shunting the alternator field directly to the battery. This results in a zero potential across the indicator lamp, causing it to go out.

17-3. Fuel Gages. Most fuel gages are operated electrically and are composed of two units: the gage, mounted on the instrument panel; and the sending unit, mounted on the fuel tank. The ignition switch is included in the fuel gage circuit so that the electrical fuel gage operates only when the ignition switch is on. Operation of the electrical gage depends on either coil action or thermostatic action.

a. *Thermostatic Fuel Gage: Self-Regulating (Fig. 17-6).* This gage configuration consists of an instrument panel gage and an electromechanical sending unit that is located inside of the fuel tank. The instrument panel gage contains an electrically heated bimetallic strip that is linked to a pointer. A bimetallic strip consists of two dissimilar metals that, when heated, expand at different rates, causing it to deflect or bend. In the case of the instrument panel fuel gage, the deflection of the bimetallic strip will result in the movement of the pointer, causing the gage to give

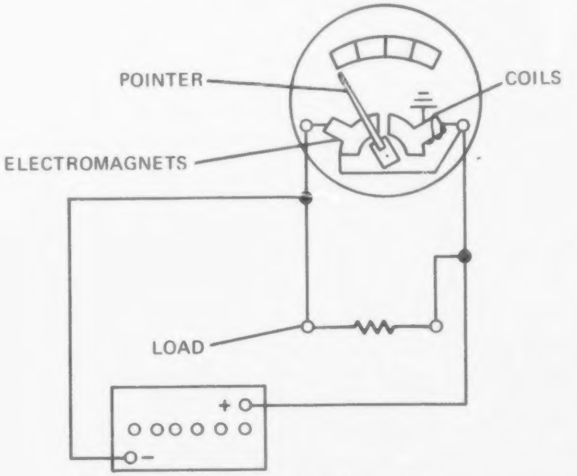


Figure 17-3. Voltmeter Operation.

352

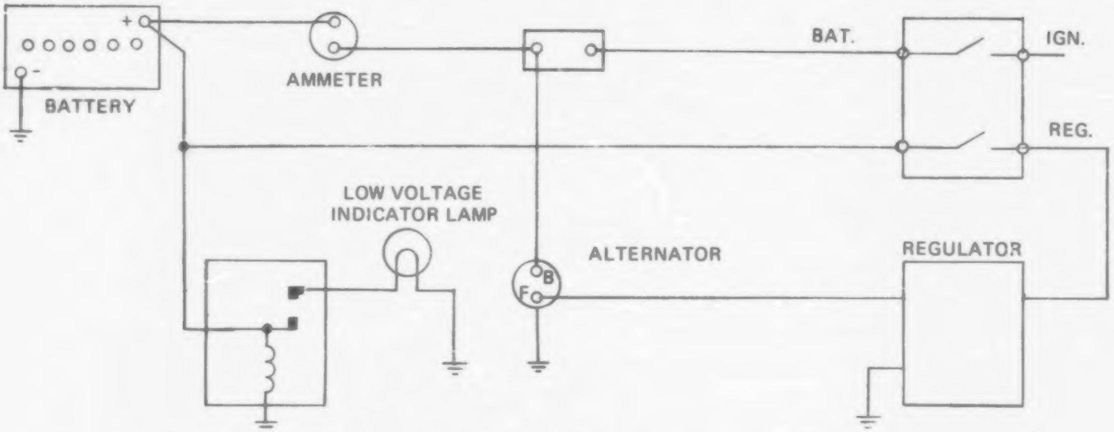

+
−
BATTERY
AMMETER
BAT.
IGN.
REG.
LOW VOLTAGE
INDICATOR LAMP
ALTERNATOR
B
F
REGULATOR

Figure 17-4. Low-Voltage Warning Lamp.

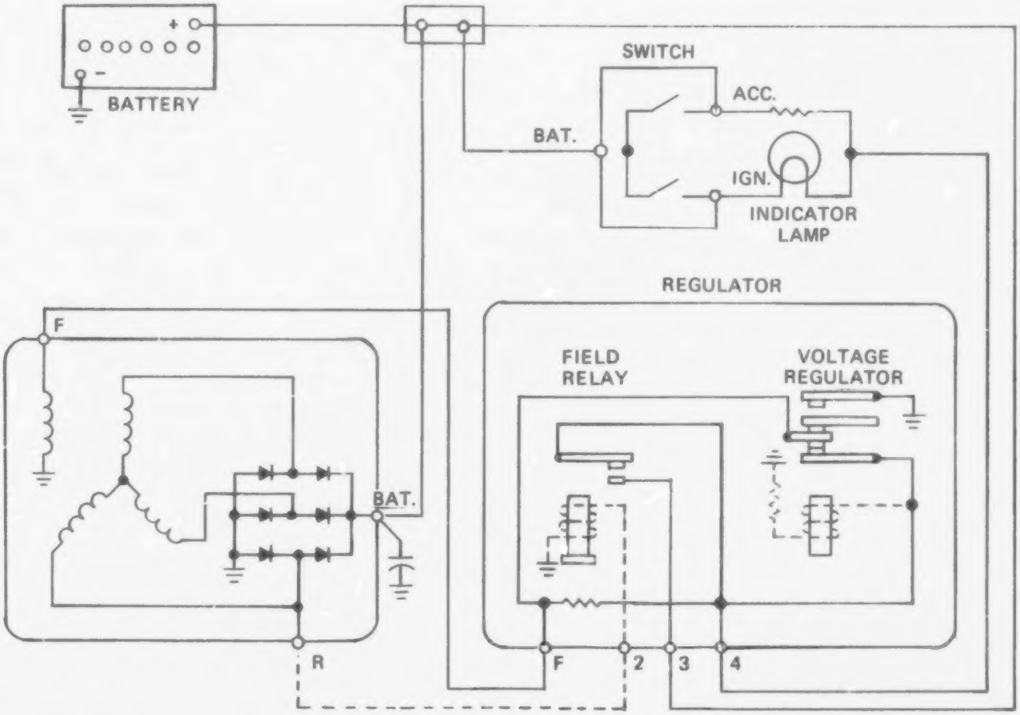

+
−
BATTERY
SWITCH
ACC.
BAT.
IGN.
INDICATOR
LAMP
REGULATOR
F
FIELD
RELAY
VOLTAGE
REGULATOR
BAT.
R
F
2
3
4

Figure 17-5. No-Charge Indicator Lamp.

TA233623

353

BEST COPY AVAILABLE

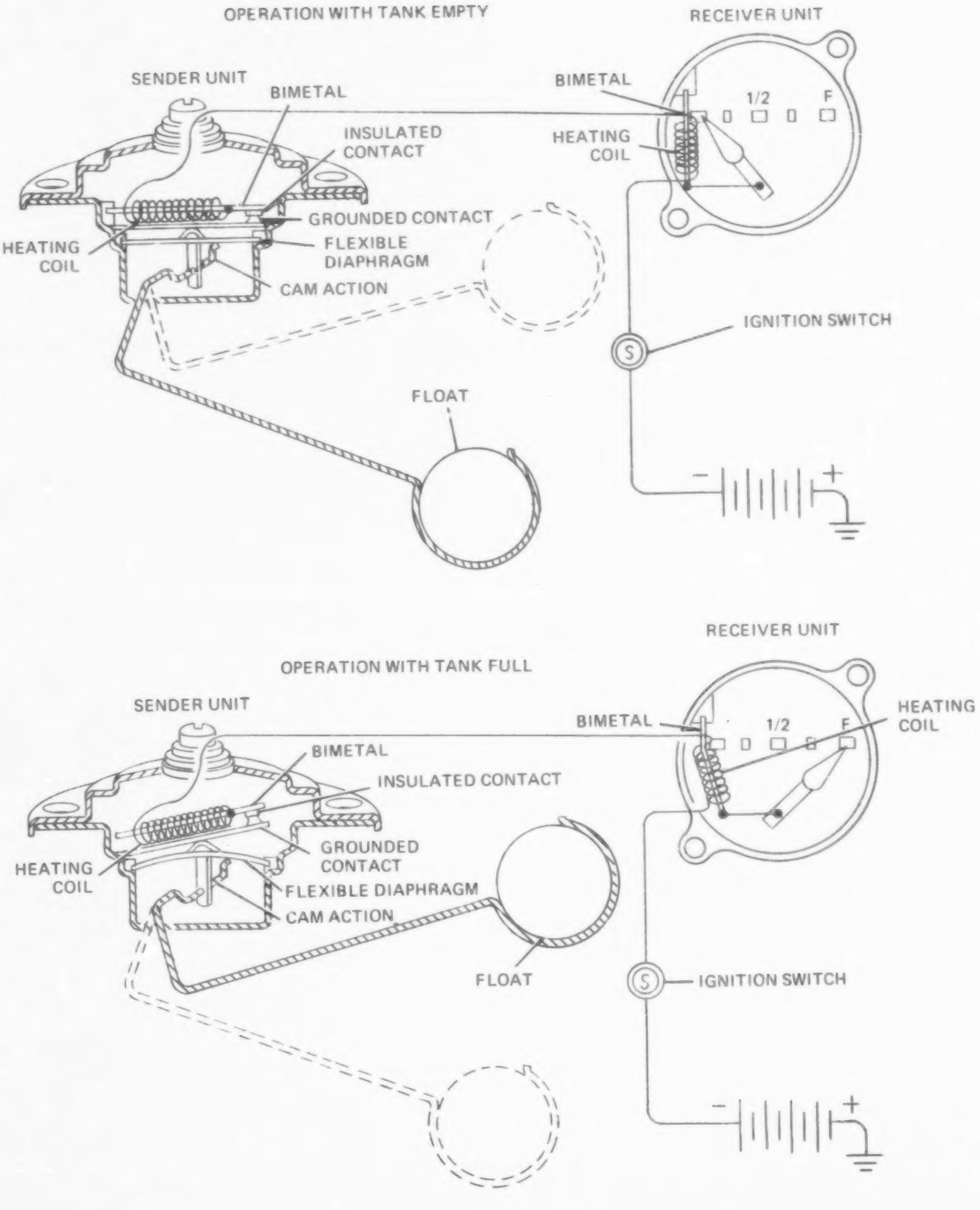

OPERATION WITH TANK EMPTY
RECEIVER UNIT
SENDER UNIT
BIMETAL
BIMETAL
1/2
F
INSULATED CONTACT
HEATING COIL
GROUNDED CONTACT
HEATING COIL
FLEXIBLE DIAPHRAGM
CAM ACTION
IGNITION SWITCH
S
FLOAT
−
+
RECEIVER UNIT
OPERATION WITH TANK FULL
HEATING COIL
SENDER UNIT
BIMETAL
1/2
F
BIMETAL
INSULATED CONTACT
GROUNDED CONTACT
HEATING COIL
FLEXIBLE DIAPHRAGM
CAM ACTION
FLOAT
S
IGNITION SWITCH
−
+

Figure 17-6. Thermostatic Fuel Gage: Self-Regulating.

TA233934

a reading. The sending unit consists of a hinged arm with a float on the end of it. The movement of the arm controls a grounded point that makes contact with another point that is attached to an electrically heated bimetallic strip. The heating coils in the tank unit and the gage are connected to each other in series. Operation is as follows.

(1) When the fuel tank is empty, the float lays on the bottom. In this position, the arm-operated cam exerts no pressure on the grounded contact. When the ignition is switched on, current flows from the ground, through the heating coil in the sending unit, through the heating coil in the instrument panel gage, and to the battery. The heating of the bimetallic strip in the sending unit causes it to deflect, opening the contact points. The opening of the points will allow the bimetallic strip to cool and return to its original position, again closing the points. The cycle of opening and closing the points will continue, supplying current pulses to the heating element in the fuel gage. The length of the pulses from the sending unit when the tank is empty will only heat the gage bimetallic strip enough to cause deflection that will move the pointer to the empty position on the gage face.

(2) When the fuel tank contains fuel, the float will raise the arm, causing the cam to push the grounded contact tighter against the bimetallic strip contact. This will cause an increase in the amount of heat required to open the contact points in the sending unit. The result will be longer current pulses to the instrument panel gage, causing higher gage readings. The gage reading will increase proportionally with the float level in the fuel tank.

(3) The tank unit will compensate for variations in electrical system voltage automatically. High voltage will increase heating, causing the points to cycle faster and if the voltage is lower, heating will decrease, causing slower point cycling.

(4) Because the gage pointer is moved by the heating and cooling of the bimetallic strip, the gage reading will not react to sudden fuel level changes caused by fuel sloshing. This will prevent erratic operation.

b. Thermostatic Fuel Gage: Externally Regulated (Fig. 17-7). The externally regulated thermostatic fuel gage uses an instrument panel

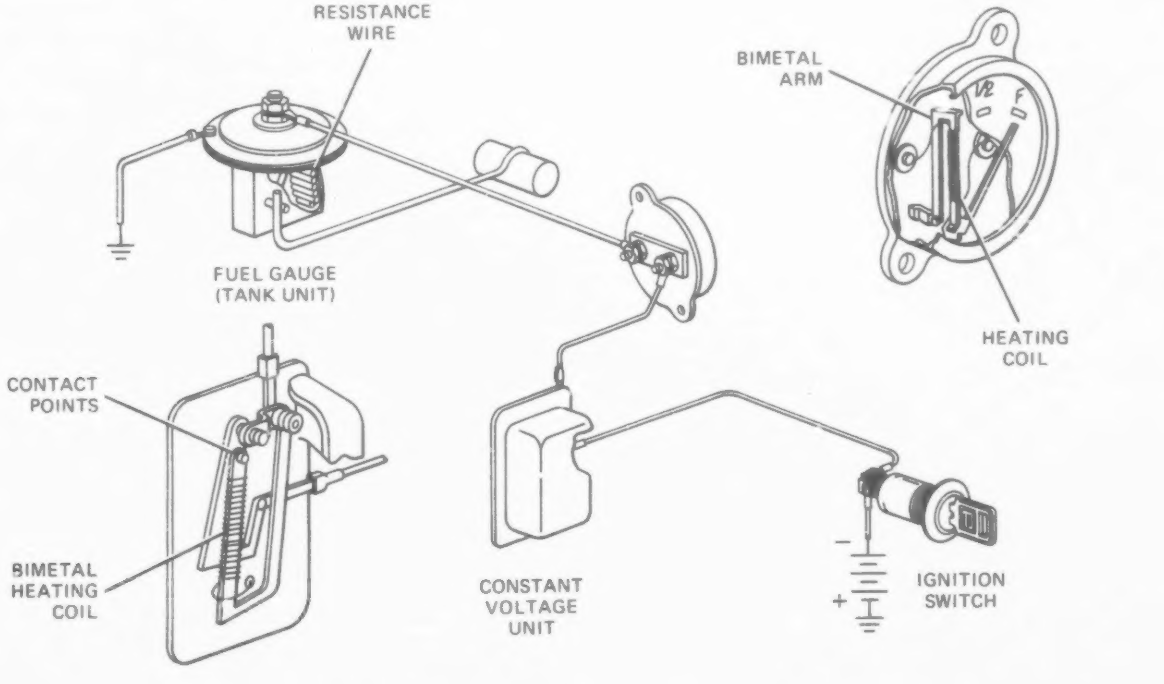


Figure 17-7. Thermostatic Fuel Gage: Externally Regulated.

TA233624

355

gage whose operation is the same as the gage used with the self-regulating system described in paragraph 17-3a. The differences in the system are the use of a variable resistance fuel tank sending unit and an external voltage-limiting device. The sending unit controls the gage through the use of a rheostat. A rheostat is a wire-wound resistance unit whose value varies with its effective length. The effective length of the rheostat is controlled in the sending unit by a sliding brush that is operated by the float arm. The power supply to the gage is kept constant through the use of a voltage limiter. The voltage limiter consists of a set of contact points that are controlled by an electrically heated bimetallic arm.

(1) When the fuel tank is empty, the float lays on the bottom. The float arm will position the contact brush so that the full length of the rheostat resistor will be utilized. The resulting high resistance will drop voltage to the gage sufficiently so that the pointer will rise only to empty.

(2) As the fuel level rises in the tank, the float will raise the float arm, which, in turn, will move the contact brush on the rheostat resistor. As the float arm moves upward, the resistance will decrease proportionally, resulting in a proportional voltage increase to the gage. The gage readings will increase proportionally, resulting in accurate readings of the fuel level in the tank.

(3) The voltage limiter effectively will ensure a constant supply of current regulated to the equivalent of 5 volts, to provide accurate gage readings regardless of electrical system voltage variations.

c. Thermostatic Fuel Gage: Differential Type (Fig. 17-8). The differential-type fuel gage system uses an instrument panel gage whose operating principles are much the same as the thermostatic gage described in paragraph 17-3a. The differential-type thermostatic gage, however, uses two electrically heated bimetallic strips that share equally in operating and supporting the gage pointer. The pointer position is obtained by dividing the available voltage between the two strips (differential). The tank unit is a rheostat type whose operating principles are much the same as the tank unit described in paragraph 17-3b. The tank unit in this system, however, contains a wire-wound resistor that is connected between two external terminals. Each one of the external terminals connects to one of the instrument panel gage bimetallic strips. The float arm moves a grounded brush that raises resistance progressively to one terminal, while lowering the resistance to the other. This causes the voltage division and resulting heat differential to the gage strips that formulate the gage readings. Two additional bimetallic strips are provided for temperature compensation. In addition, one of these blades operates contact points to limit voltage to approximately 5 volts.

(1) When the tank is half full, the float arm positions the contact brush midway of the rheostat. This causes equal resistance values to each sending unit circuit,resulting in equal heating of the gage bimetallic strips, causing the gage to read one-half.

(2) Fuel levels above or below half will cause the tank unit to divide the voltage to the gage bimetallic strips in the correct proportions to

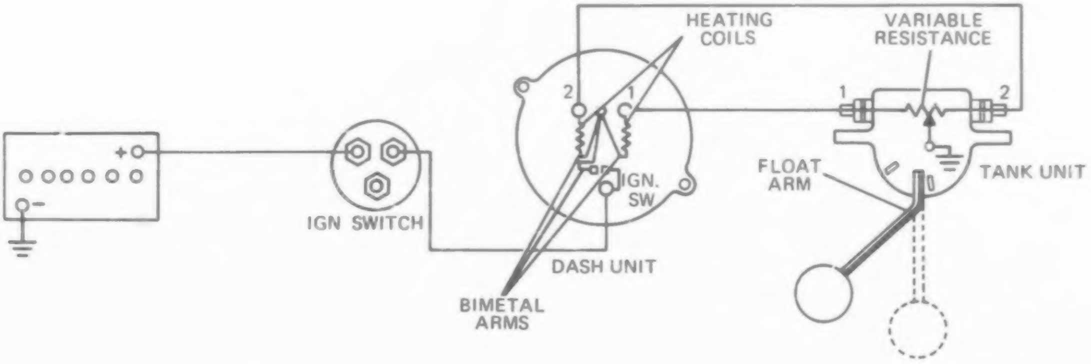


Figure 17-8. Thermostatic Fuel Gage: Differential Type.

TA233625

create correct gage readings. An example would be a one-quarter full fuel tank. At this level, the tank unit would divide the voltage so that 75 percent of the current would flow through the right-side strip and 25 percent would flow through the left-side strip. This would produce a one-quarter gage reading.

d. Magnetic Fuel Gage (Fig. 17-9). The basic instrument panel gage consists of a pointer that is mounted on an armature. Depending on the gage design, the armature may contain either one or two poles. The gage is motivated by a magnetic field that is created by two separate magnetic coils that are contained within the gage. One of these coils is connected directly to the battery, producing a constant magnetic field. The other coil produces a variable field whose strength is determined by a rheostat-type tank unit whose operation is the same as the one described in paragraph 17-3b. The coils usually are placed 90 degrees apart.

(1) When the tank is empty, the tank unit creates a very high resistance. This causes the variable magnetic coil to produce almost no magnetic field. Therefore the armature poles on the gage pointer will be attracted to the constant magnetic coil. The pointer will point to empty when the armature is in this position.

(2) When the tank is full, the tank unit will create no resistance. Therefore, the armature poles on the gage pointer will be positioned midway between the coils. When the armature is in this position, the pointer will indicate a full reading.

(3) Variations in electrical system voltage will affect both magnetic coils equally and, therefore, will not upset the differential created between them. Because of this, the magnetic gage is self-regulating and requires no voltage-limiting devices.

(4) The magnetic gage is very sensitive to road shock and sudden changes in voltage such as those caused by the fuel sloshing in the tank. Because of this, the armature of the instrument panel gage will be fitted with a damping device or a flywheel.

17-4. Pressure Gages.

a. Usage. Pressure gages are used widely in automotive applications to keep track of things such as engine oil pressure, fuel line pressure, airbrake system pressure,and the pressures of the hydraulic systems in special purpose vehicles. Depending on the equipment, a mechanical or an electric pressure gage may be utilized.

b. Electric Gage (Fig. 17-10). The instrument panel gage may be of the thermostatic type described in paragraph 17-3a, or of the magnetic type described in paragraph 17-3d. The sending

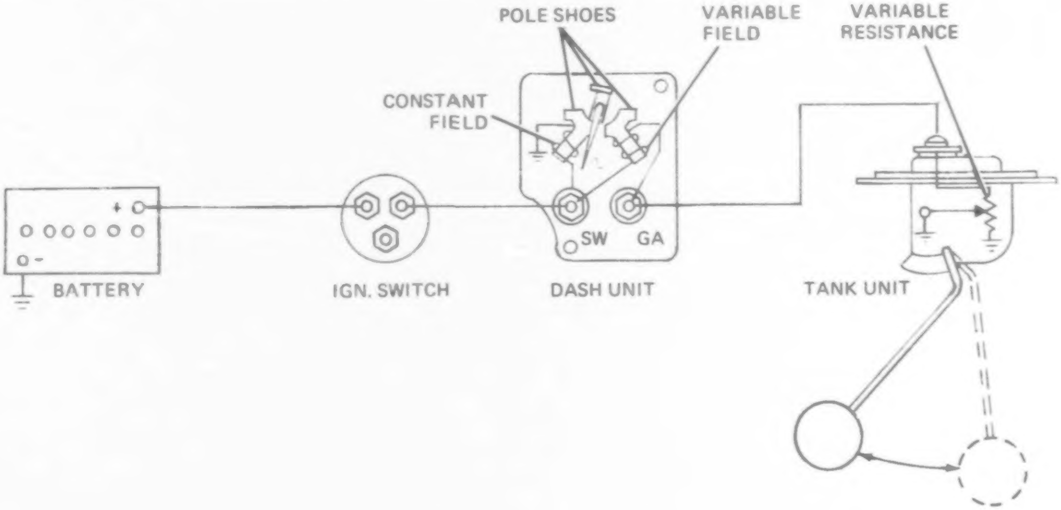
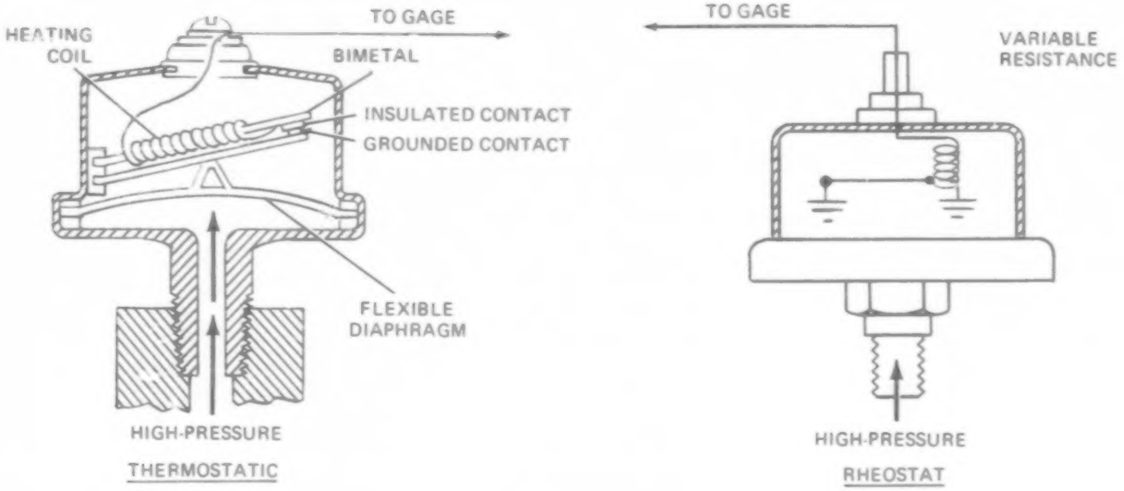


Figure 17-9. Magnetic Fuel Gage.

TA233626

357

BEST COPY AVAILABLE



HIGH-PRESSURE THERMOSTATIC

HIGH-PRESSURE RHEOSTAT

Figure 17-10. Types of Sending Units for Pressure Gages.

unit that is used with each gage type varies as follows:

(1) The sending unit that is used with the thermostatic gage utilizes a flexible diaphragm that moves a grounded contact. The contact that mates with the grounded contact is attached to a heated bimetallic strip. The flexing of the diaphragm, which is done with pressure changes, varies the point tension. The different positions of the diaphragm produce gage readings in the same manner as the different positions of the float arm of the tank sender in paragraph 17-3a.

(2) The sending unit that is used with the magnetic-type gage also translates pressure into the flexing of a diaphragm. In the case of the magnetic gage sending unit however, the diaphragm operates a rheostat. The flexing of the diaphragm in the pressure sender produces the same results as does the movement of the float arm in the tank sender described in paragraph 17-3d. This type of sender also can be used with a thermostatic-type gage if a voltage-limiting device like the one used in paragraph 17-3b also is used.

c. Mechanical Gages (Fig. 17-11). The mechanical pressure gage uses a thin tube to carry an actual pressure sample directly to the gage. The gage basically consists of a hollow, flexible C-shaped tube called a bourden tube. As fluid or air pressure is applied to the bourden tube, it will tend to straighten out. As it straightens, the attached gage pointer will move, giving a reading.

d. Indicator Lamp (Fig. 17-12). The oil pressure warning light is used in place of a gage on many vehicles. The warning light, although not an accurate indicator, is valuable because of its high visibility in the event of a low oil pressure condition. Because an engine can fail or be damaged permanently in less than a minute of operation without oil pressure, the warning light often is used as a backup for a gage to attract instant attention to a malfunction. The warning light receives battery power through the ignition switch. The circuit to ground is completed through the engine sender switch. The sender switch consists of a pressure-sensitive diaphragm that operates a set of contact points. The contact points are calibrated to turn on the warning light whenever the engine oil pressure drops below approximately 15 psi (103.4 kPa), depending on the equipment.

17-5. Temperature Gages (Fig. 17-13).

a. Usage. The temperature gage is a very important indicator in automotive equipment. The most common use is to indicate engine, transmission, and differential oil temperatures and engine coolant temperatures. Depending on the type of equipment, the gage may be electric or mechanical.

TA233627

358

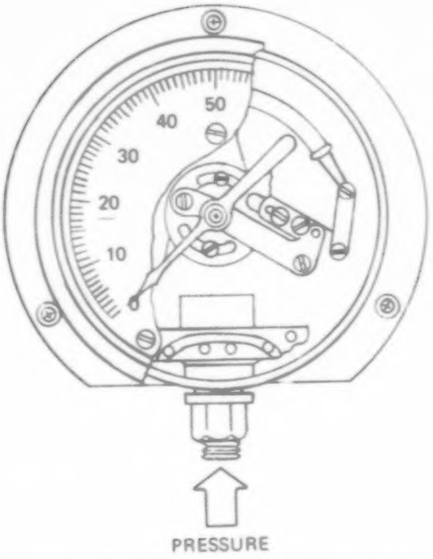

50
40
30
20
10
PRESSURE

Figure 17-11. Mechanical Pressure Gages.

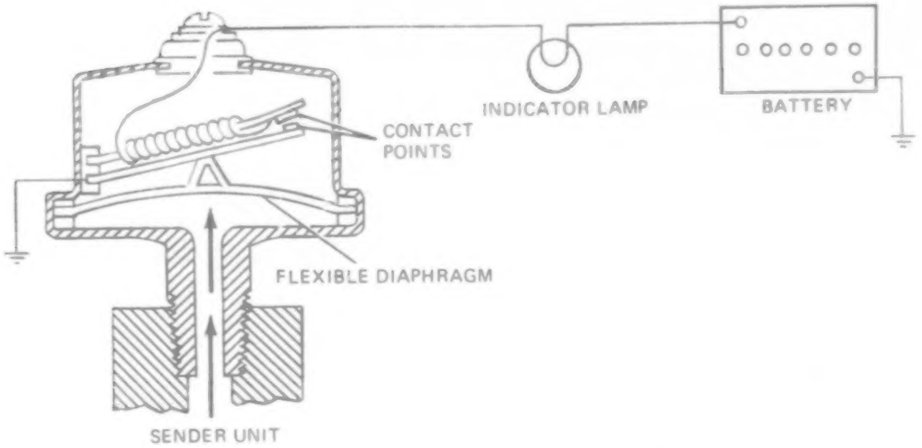

INDICATOR LAMP
BATTERY
CONTACT POINTS
FLEXIBLE DIAPHRAGM
SENDER UNIT

Figure 17-12. Oil Pressure Warning Lamp.

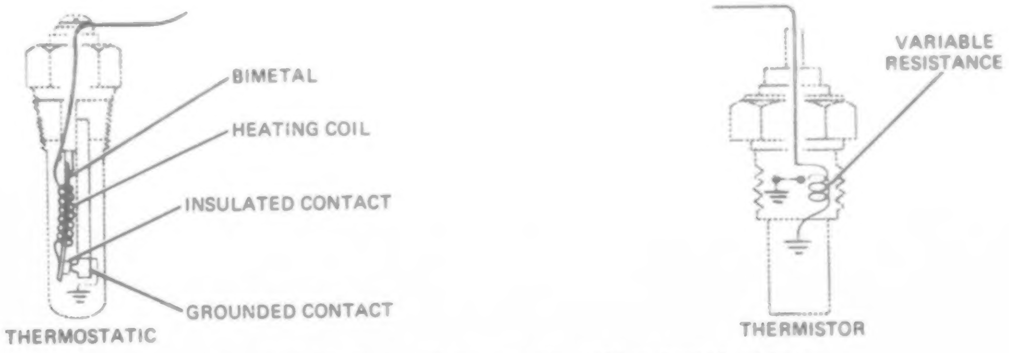

BIMETAL
HEATING COIL
INSULATED CONTACT
GROUNDED CONTACT
THERMOSTATIC
VARIABLE RESISTANCE
THERMISTOR

Figure 17-13. Types of Temperature Gage Sending Units.

TA233628

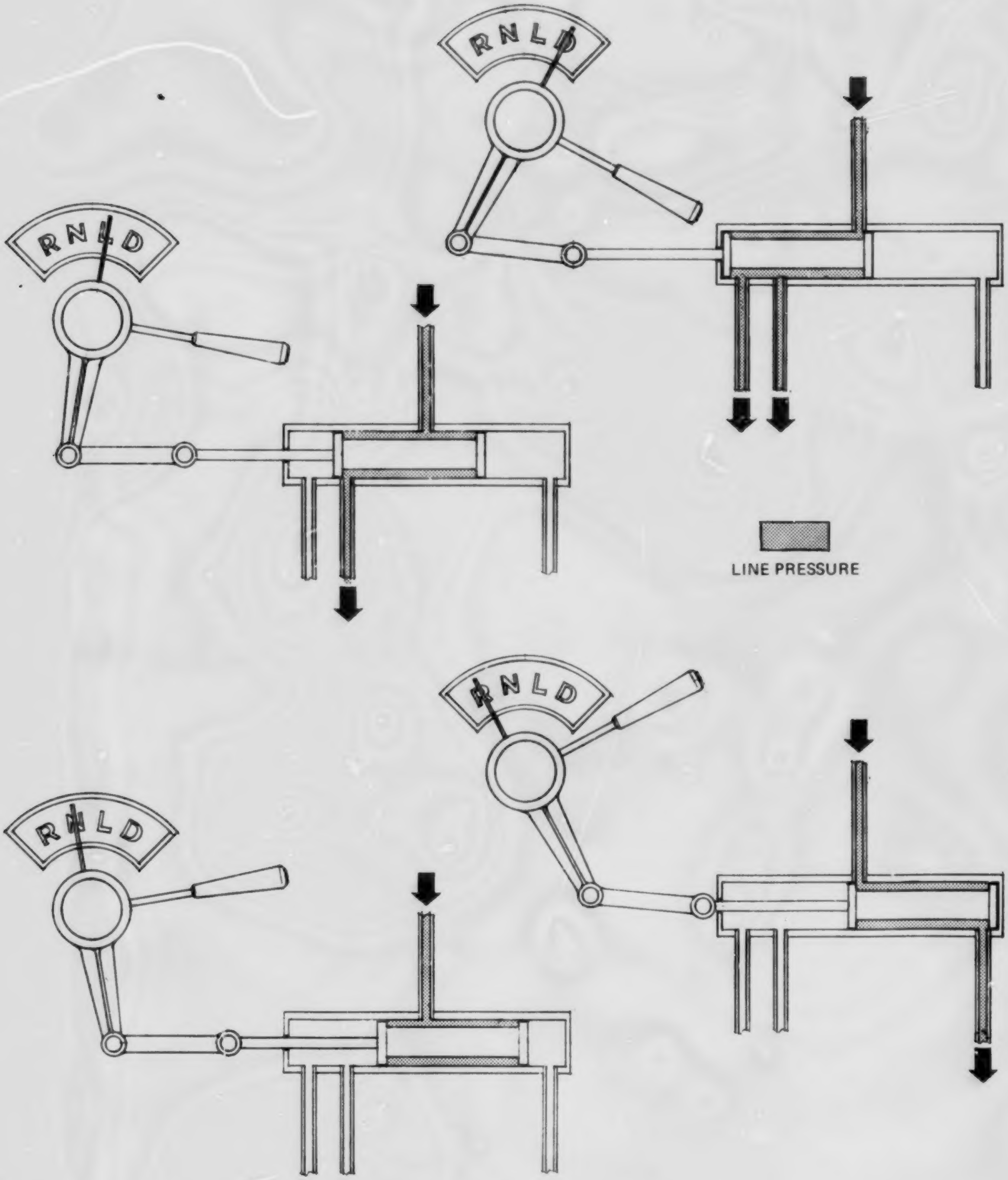

RNLD
RNLD
LINE PRESSURE
RNLD
RNLD

Figure 23-14. Manual Valve Operation.

TA233711

inward by specially calibrated springs that allow the weights to move from a fully retracted to a fully extended position within a desired output shaft speed range. The spool valve is in a position where all line pressure is blocked when the governor weights are fully retracted. As the weights move outward, the spool valve gradually opens the line pressure port to the governor pressure port. The result is an approximate linear speed and governor pressure increase. A hypothetical governor is illustrated in figure 23-15. A graph showing the typical relationship between governor pressure and speed is shown in figure 23-16.

d. Shift Valve. The shift valve is a simple balance-type spool valve that selects between low and high gear when the manual valve is in the drive (D) position. Governor pressure acts on the spool valve in one direction, trying to push the spool towards the high-gear position. At the same time, spring pressure modulated by the position of the accelerator pedal tries to push the spool toward the low-gear position. The decision of the shift valve is dependent on which pressure is greater: governor or throttle. The shift valve also contains a device known as a throttle plug. At full throttle the throttle plug makes physical contact with the shift valve spool, forcing it into the low-gear position. This is how a forced downshift (passing gear) is initiated. A hypothetical shift valve is illustrated in figure 23-17.

e. Operation. The following subparagraphs describe the operation of a hypothetical hydraulic system for a two-speed automatic transmission in all of its modes of operation. It must be noted that a reverse band rather than a reverse clutch is used in the hypothetical transmission. The reason for this is to allow a wider variety of holding elements to be illustrated.

(1) When the shift lever is placed in neutral (N) (fig. 23-18), line pressure is blocked at the manual valve and none of the frictional elements are applied.

(2) When the shift lever is placed in drive-low (L) (fig. 23-19), the manual valve delivers line pressure directly to the low band. The compound planetary gear train (para 23-9) then is in low gear.

(3) When the gearshift lever is placed in reverse (R) (fig. 23-20), the manual valve delivers line pressure directly to the reverse band. The compound planetary gear train (para 23-9) then is in low gear.

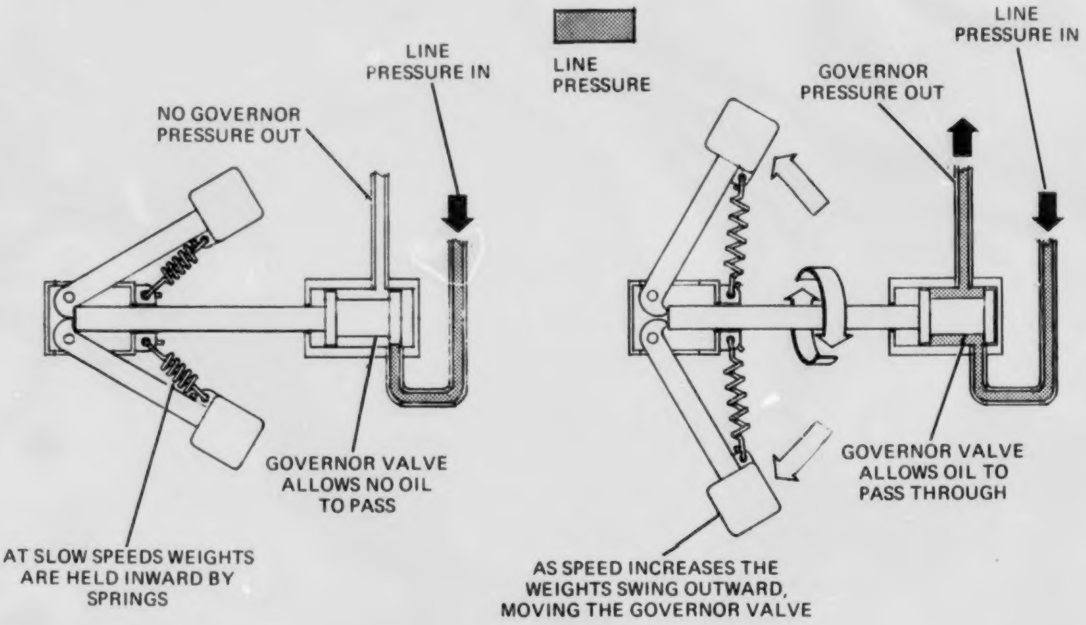

▨ LINE PRESSURE
LINE PRESSURE IN
NO GOVERNOR PRESSURE OUT
GOVERNOR VALVE ALLOWS NO OIL TO PASS
AT SLOW SPEEDS WEIGHTS ARE HELD INWARD BY SPRINGS
LINE PRESSURE IN
GOVERNOR PRESSURE OUT
GOVERNOR VALVE ALLOWS OIL TO PASS THROUGH
AS SPEED INCREASES THE WEIGHTS SWING OUTWARD, MOVING THE GOVERNOR VALVE

Figure 23-15. Operation of the Governor.

TA233712

L58

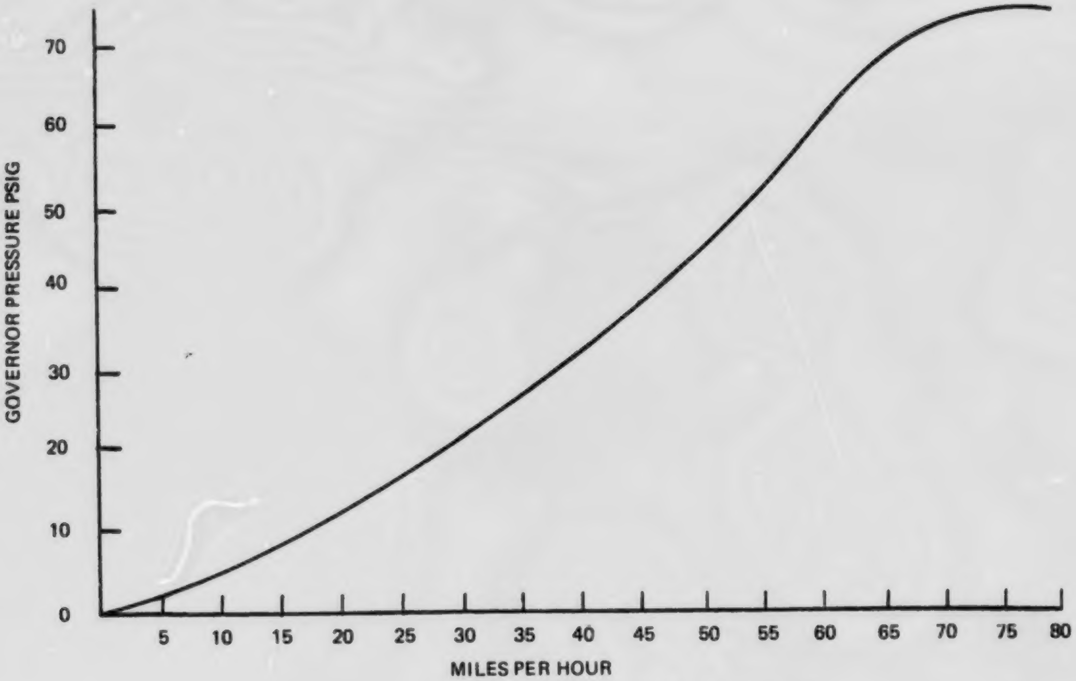


Figure 23-16. Typical Governor Pressure Versus Speed.

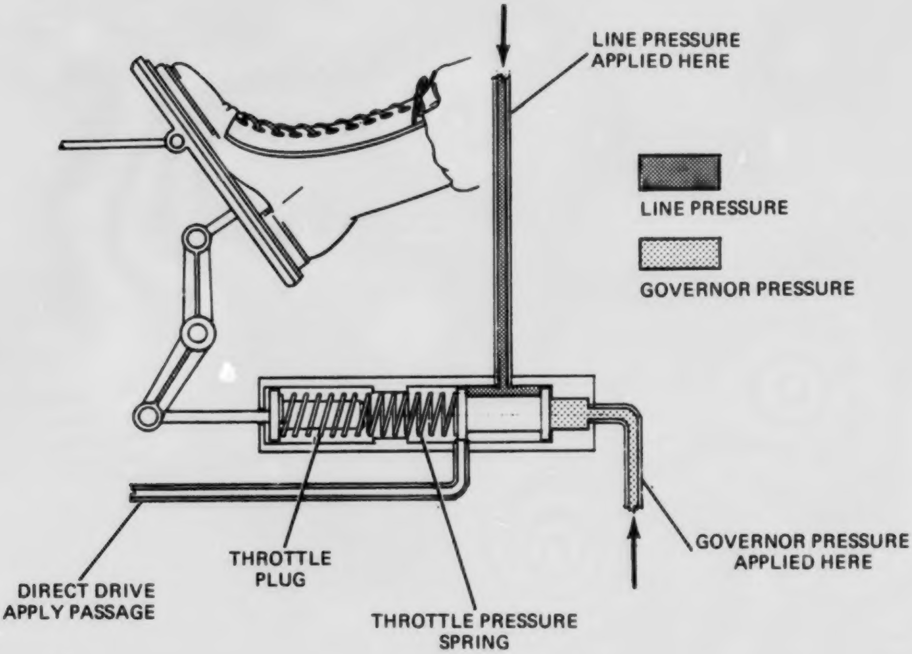

LINE PRESSURE APPLIED HERE
▩ LINE PRESSURE
▨ GOVERNOR PRESSURE
GOVERNOR PRESSURE APPLIED HERE
THROTTLE PLUG
DIRECT DRIVE APPLY PASSAGE
THROTTLE PRESSURE SPRING

Figure 23-17. Shift Valve.

TA233713

459

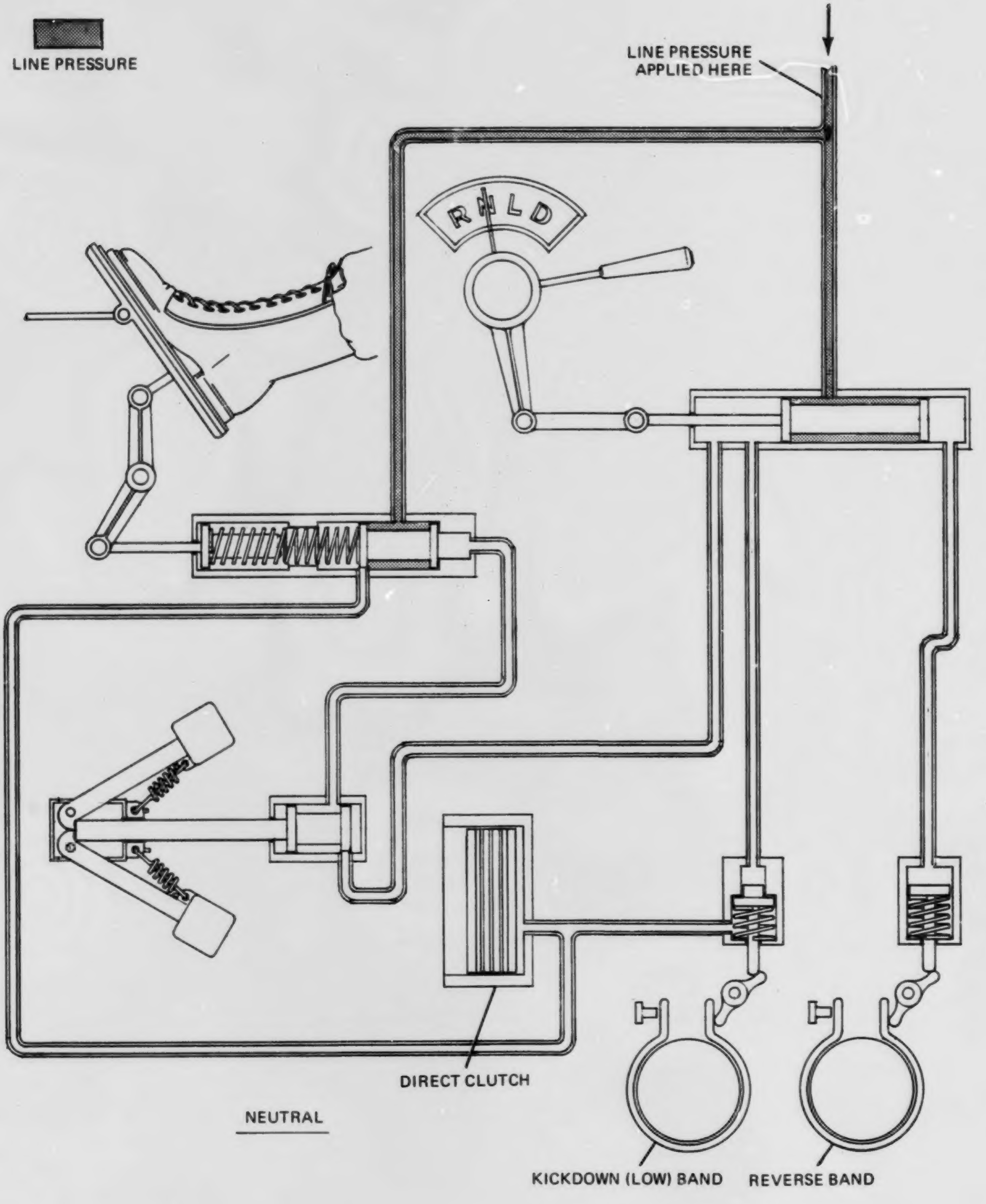

▨ LINE PRESSURE
LINE PRESSURE APPLIED HERE
R N L D
DIRECT CLUTCH
NEUTRAL
KICKDOWN (LOW) BAND
REVERSE BAND

Figure 23-18. Transmission Hydraulic System in Neutral.

TA233714

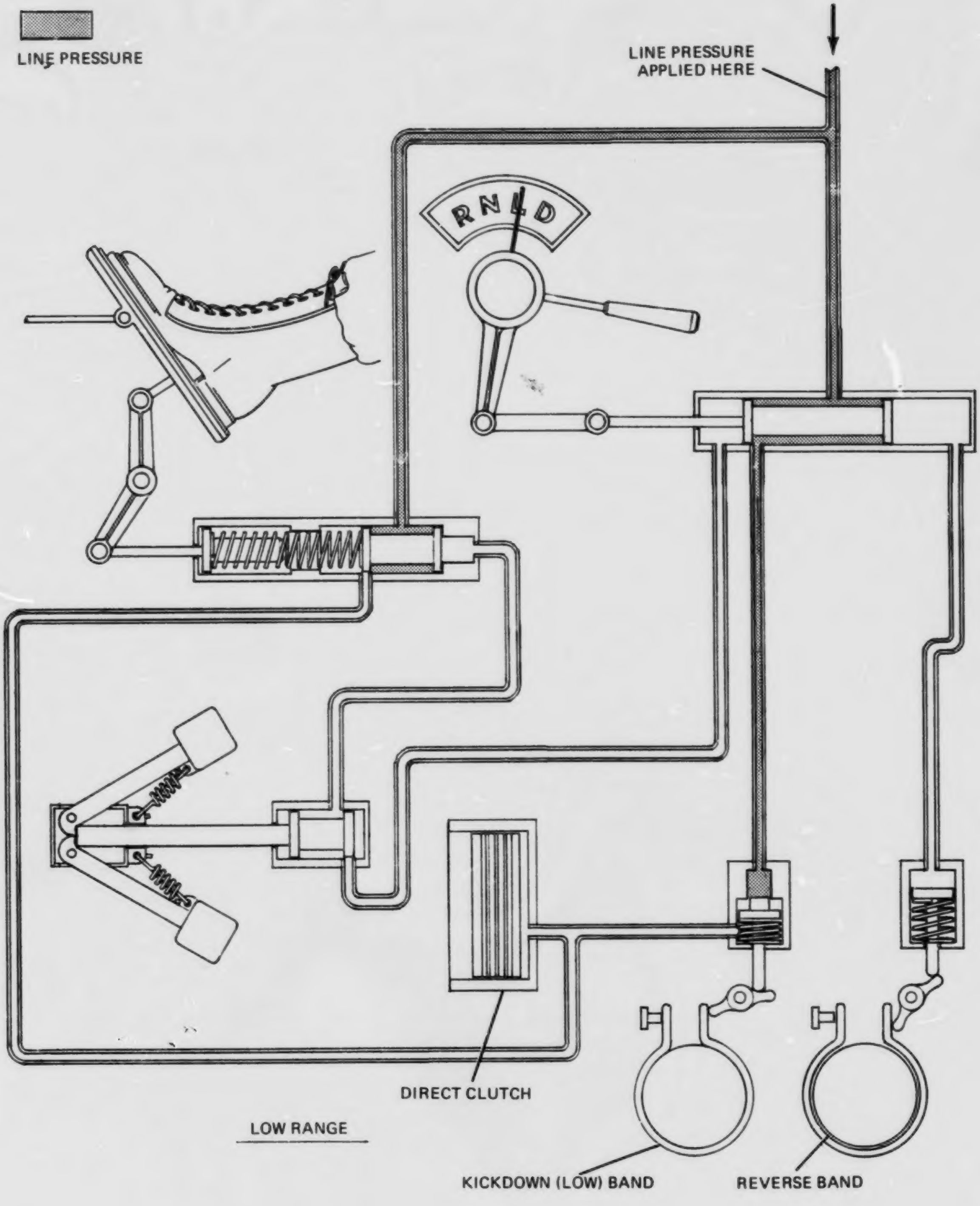

LINE PRESSURE
LINE PRESSURE APPLIED HERE
R N L D
DIRECT CLUTCH
LOW RANGE
KICKDOWN (LOW) BAND
REVERSE BAND

Figure 23-19. Transmission Hydraulic System in Low (L) Range.

TA233715

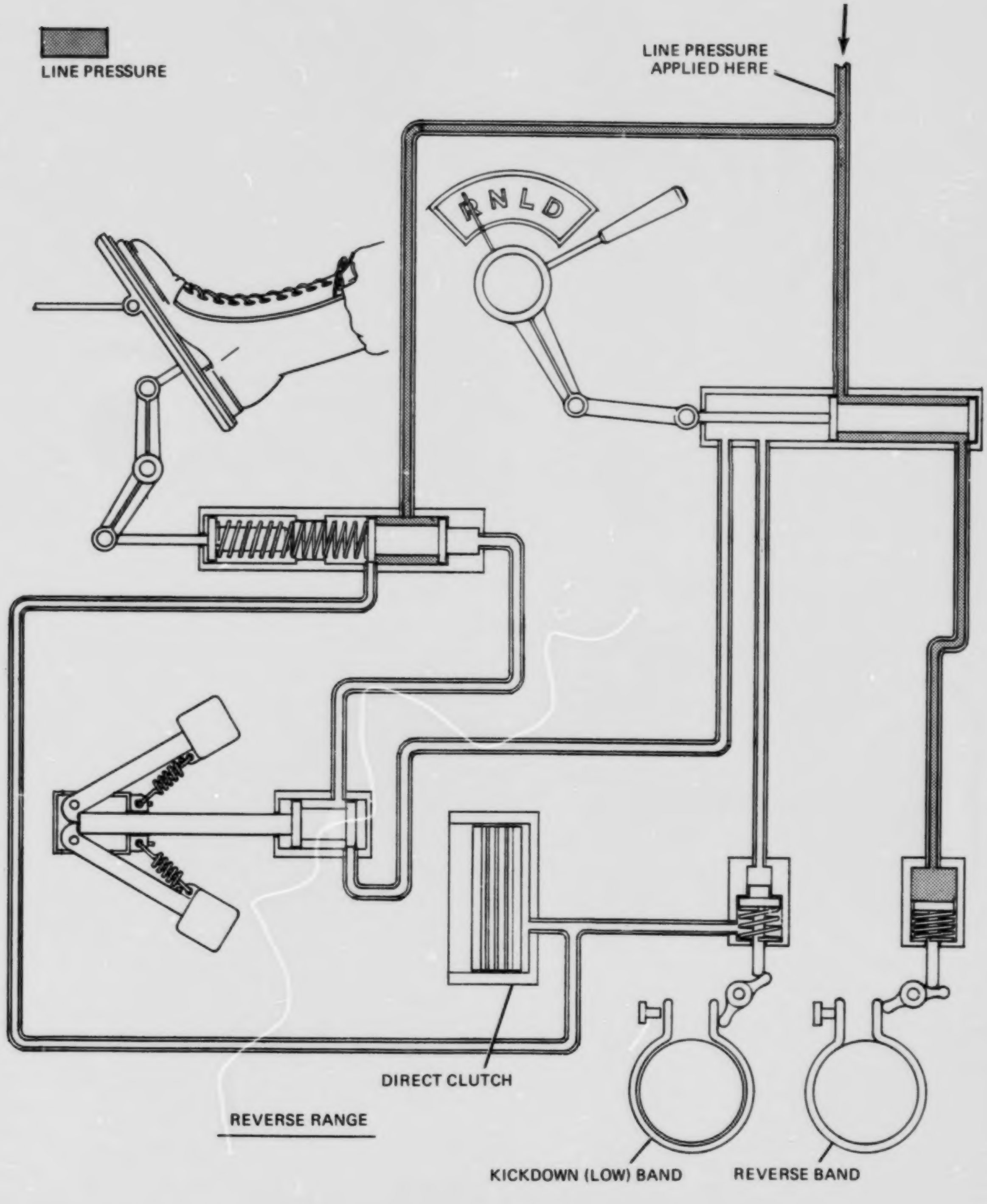

▨ LINE PRESSURE
LINE PRESSURE APPLIED HERE
R N L D
DIRECT CLUTCH
REVERSE RANGE
KICKDOWN (LOW) BAND
REVERSE BAND

Figure 23-20. Transmission Hydraulic System in Reverse (R).

TA233716

462

(4) When the gearshift lever is placed in drive (D) (fig. 23-21), the manual valve delivers line pressure directly to the low band and to the governor. Because the vehicle is not moving, the governor does not supply pressure to the shift valve and the compound planetary gear train (para 23-9) remains in low gear.

(5) As the vehicle begins to move with the gearshift lever in drive, the transmission is in low gear, providing the engine with the necessary mechanical advantage to accelerate the vehicle to speed. As the vehicle speed increases, the governor pressure rises proportionately. When vehicle speed reaches a point where the governor pressure on one side of the shift valve spool can overcome the throttle spring pressure on the other side of the shift valve spool, the spool moves to the direct or high-gear position (fig. 23-22). As the valve spool moves, the shift valve begins to deliver line pressure to apply the direct clutch and release the low band. The low band, so that it can be released while it is still under apply pressure, uses a double-acting servo. The double-acting servo can be released by applying pressure under the piston. The diameters of the piston and the bore of the double-acting servo are stepped so that the pressure under the piston will act on a greater surface area and therefore overcome apply pressure. The application of the direct clutch and the release of the low band place the compound planetary gear train (para 23-9) in high gear or direct drive. The pressure exerted by throttle spring against the shift valve spool increases proportionately as the accelerator is depressed. This in turn will proportionately raise the vehicle speed at which automatic upshifts occur.

(6) If a situation arises when quick acceleration is needed, the operator can initiate a forced downshift by pushing the accelerator to the floor (fig. 23-23). This action causes the throttle plug to contact the shift valve spool, forcing it into the low-gear position. This action cuts off line pressure to the direct clutch and the release side of the low-band servo, causing the direct clutch to release as the low band applies. This places the compound planetary gear train (para 23-9) in low gear.

f. Auxiliary Devices. The hypothetical hydraulic system illustrated above is a good learning tool; however, to actually function, many more devices are necessary. The following devices are necessary in addition to the basic operation of the hydraulic system:

(1) Devices called accumulators (fig. 23-24) are connected into the pressure supply lines of selected planetary gearset holding elements. An accumulator is a spring-loaded piston that causes line pressure to build gradually when the element is applied. This gives a cushioning effect to its application, resulting in smoother shifting of the transmission.

(2) Valves are installed to prevent the transmission from being shifted into reverse during forward movement and to prevent a forced downshift above a predetermined speed.

(3) A modulator (fig. 23-25) is used in some automatic transmissions in place of throttle linkage. The modulator is a diaphragm device that uses engine manifold vacuum to indicate engine load to the shift valve.

To get an idea of how complicated the hydraulic system really is, a schematic view of an actual hydraulic system is shown in figure 23-26.

463

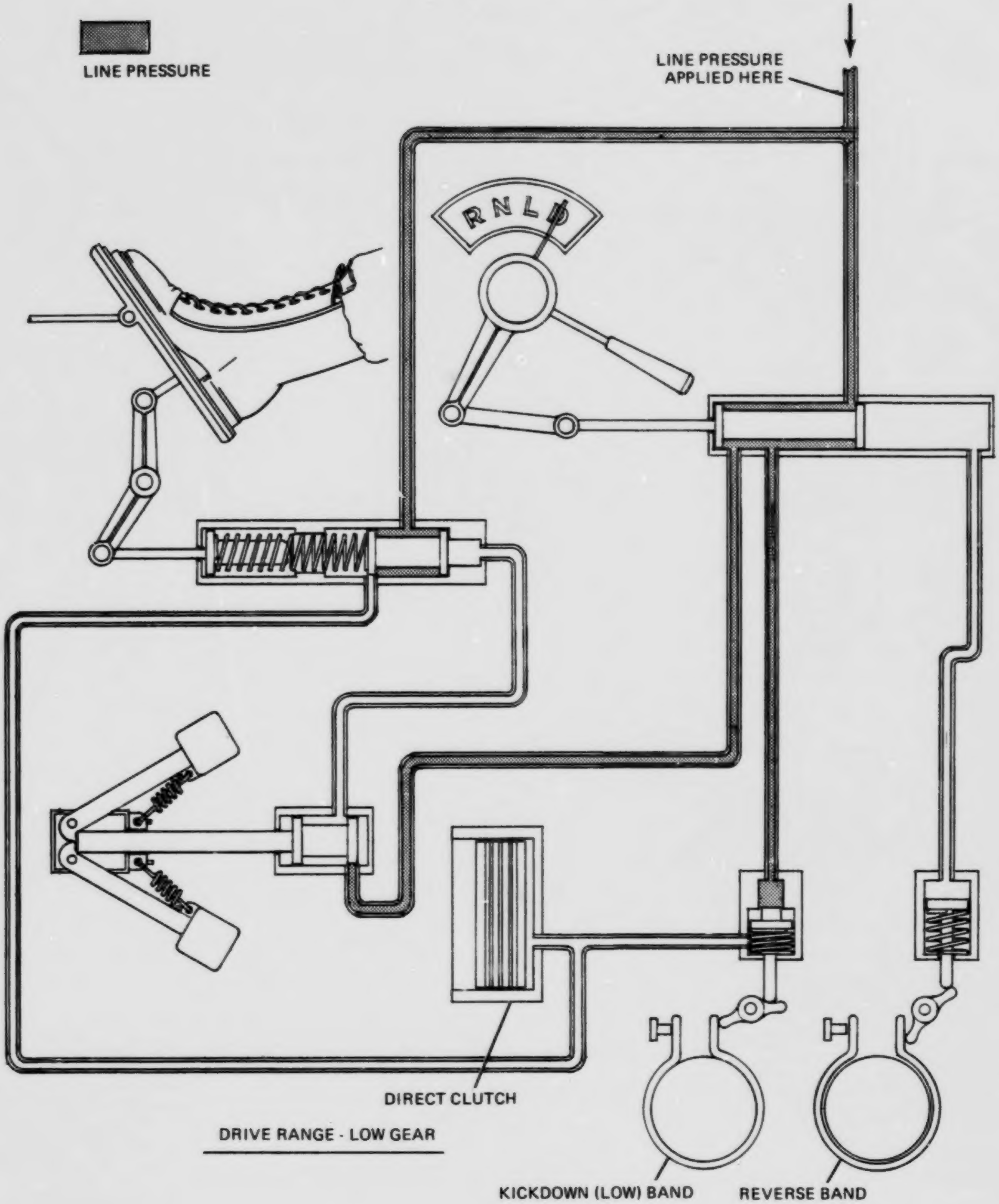

▨ LINE PRESSURE
LINE PRESSURE APPLIED HERE
R N L D
DIRECT CLUTCH
DRIVE RANGE - LOW GEAR
KICKDOWN (LOW) BAND
REVERSE BAND

Figure 23-21. Transmission Hydraulic System in Drive (D) – Low Range.

TA233717

464

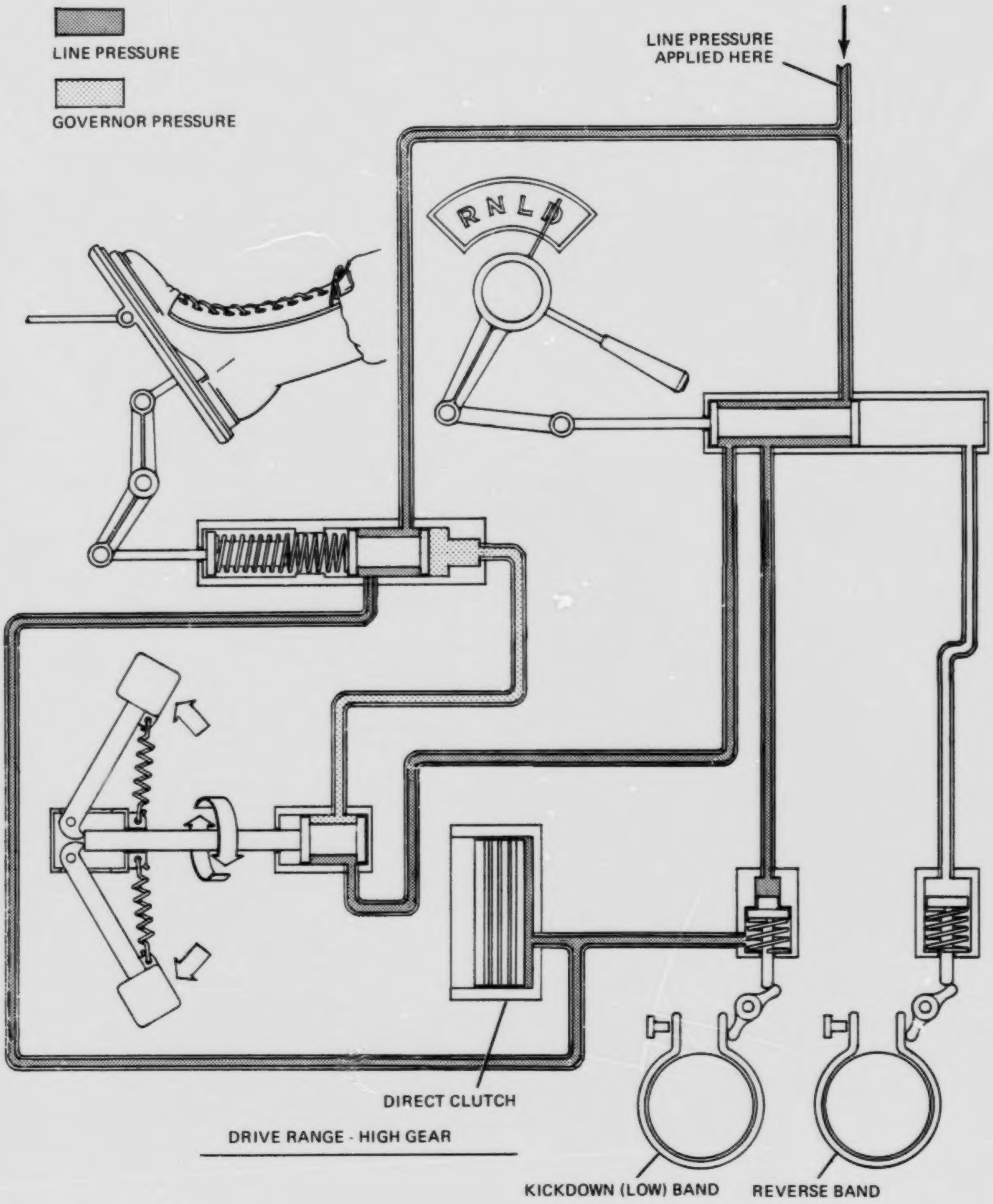

▨ LINE PRESSURE
▨ GOVERNOR PRESSURE
LINE PRESSURE APPLIED HERE
R N L D
DIRECT CLUTCH
DRIVE RANGE - HIGH GEAR
KICKDOWN (LOW) BAND
REVERSE BAND

Figure 23-22. Transmission Hydraulic System in Drive (D) – Direct Range.

TA233718

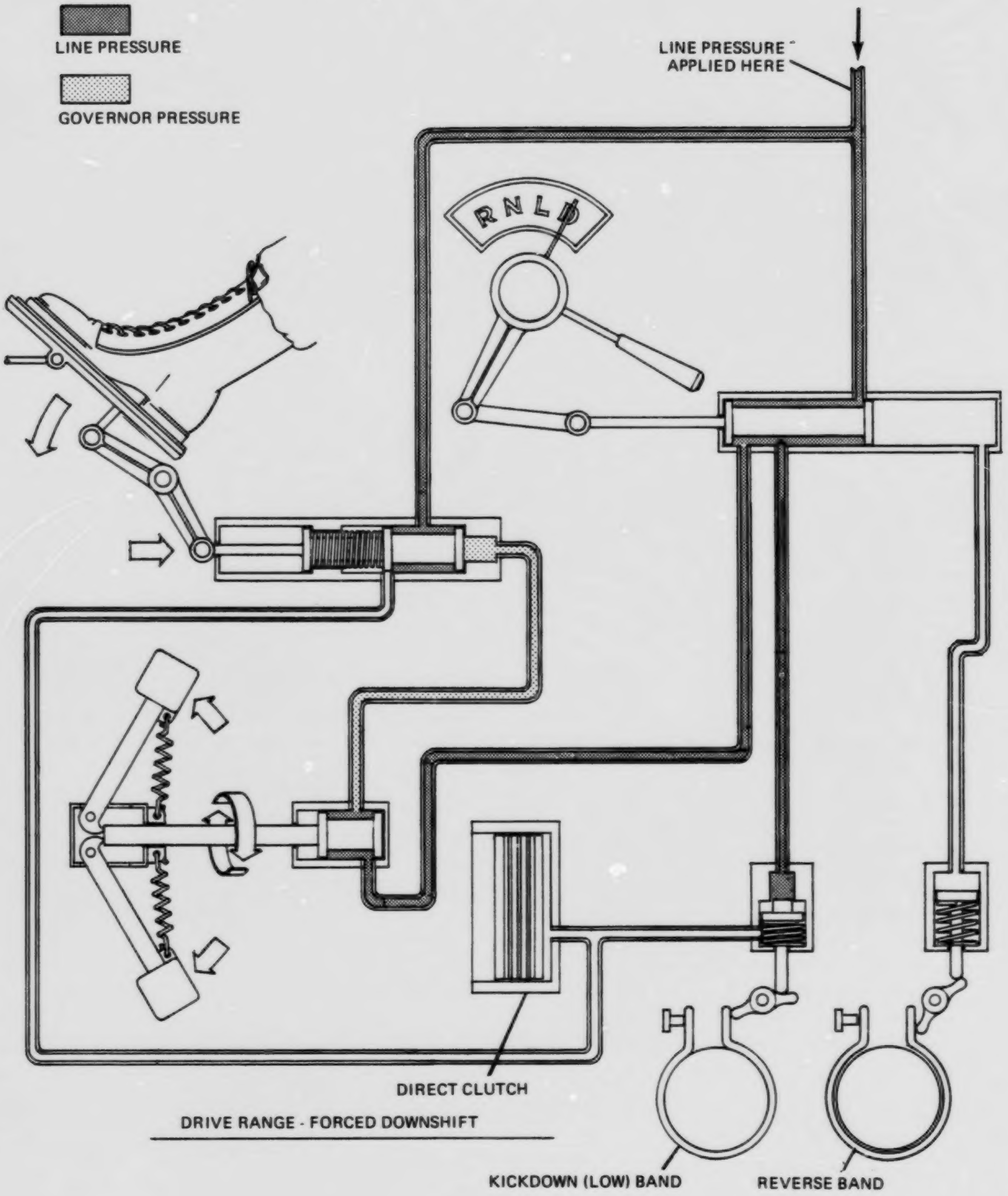

LINE PRESSURE
GOVERNOR PRESSURE
LINE PRESSURE APPLIED HERE
R N L D
DIRECT CLUTCH
DRIVE RANGE - FORCED DOWNSHIFT
KICKDOWN (LOW) BAND
REVERSE BAND

Figure 23-23. Transmission Hydraulic System in Drive (D) – Forced Downshift Range.

TA233719

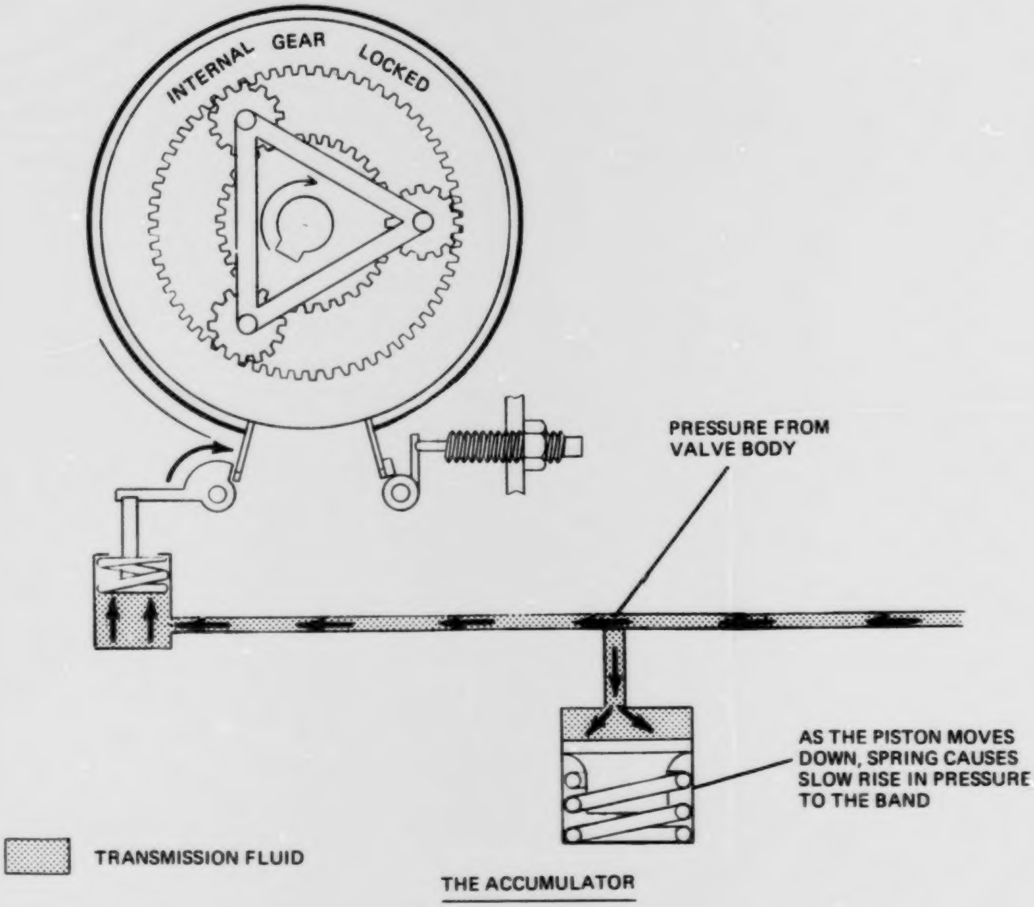
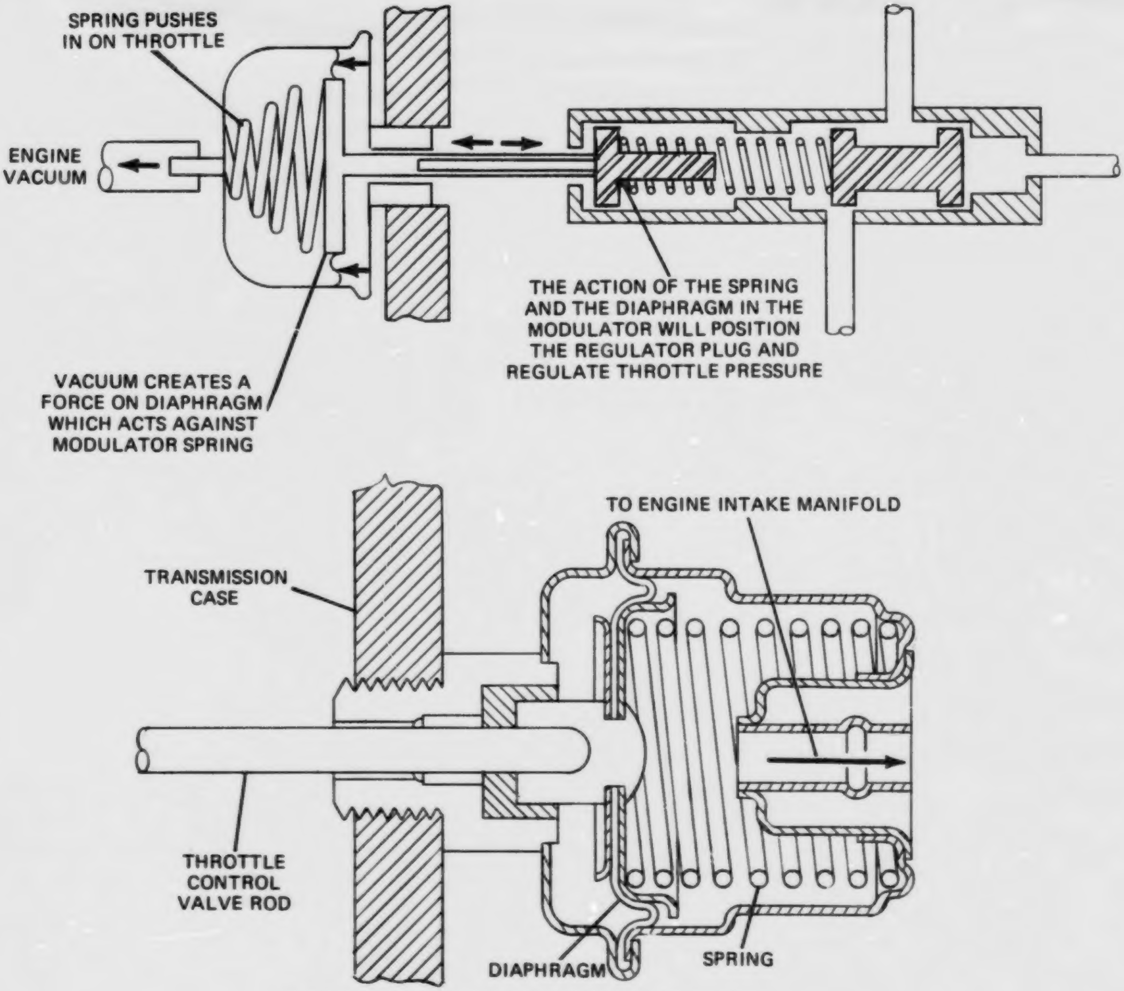

INTERNAL GEAR LOCKED
PRESSURE FROM VALVE BODY
AS THE PISTON MOVES DOWN, SPRING CAUSES SLOW RISE IN PRESSURE TO THE BAND
▨ TRANSMISSION FLUID
THE ACCUMULATOR

Figure 23-24. Operation of the Accumulator.

TA233720


SPRING PUSHES IN ON THROTTLE
ENGINE VACUUM
THE ACTION OF THE SPRING AND THE DIAPHRAGM IN THE MODULATOR WILL POSITION THE REGULATOR PLUG AND REGULATE THROTTLE PRESSURE
VACUUM CREATES A FORCE ON DIAPHRAGM WHICH ACTS AGAINST MODULATOR SPRING
TO ENGINE INTAKE MANIFOLD
TRANSMISSION CASE
THROTTLE CONTROL VALVE ROD
DIAPHRAGM
SPRING

MODULATOR REGULATING THROTTLE PRESSURE

Figure 23-25. Transmission Modulator.

TA233721

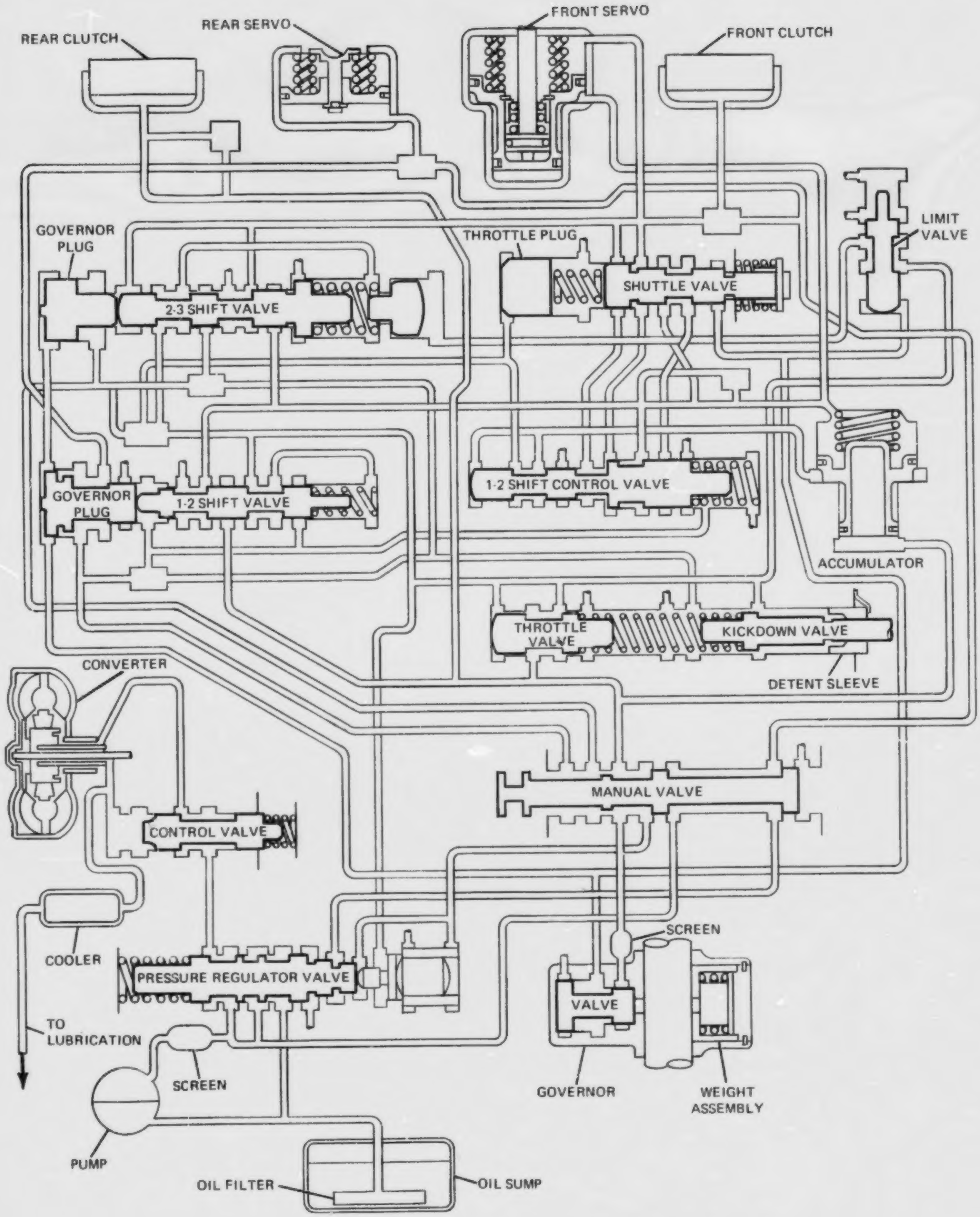

FRONT SERVO
REAR SERVO
FRONT CLUTCH
REAR CLUTCH
LIMIT VALVE
GOVERNOR PLUG
THROTTLE PLUG
2-3 SHIFT VALVE
SHUTTLE VALVE
GOVERNOR PLUG
1-2 SHIFT VALVE
1-2 SHIFT CONTROL VALVE
ACCUMULATOR
THROTTLE VALVE
KICKDOWN VALVE
DETENT SLEEVE
CONVERTER
MANUAL VALVE
CONTROL VALVE
SCREEN
COOLER
PRESSURE REGULATOR VALVE
VALVE
TO LUBRICATION
SCREEN
GOVERNOR
WEIGHT ASSEMBLY
PUMP
OIL FILTER
OIL SUMP

Figure 23-26. Hydraulic Schematic of a Typical Three-Speed Automatic Transmission.

TA233722

469

BEST COPY AVAILABLE

CHAPTER 24

CROSS-DRIVE TRANSMISSION

Section I. FUNCTION

24-1. General. Several models of cross-drive transmissions are in use, differing in some details from each other. All, however, operate in a similar manner. This type of transmission is a combination transmission and steering unit for use on tracked vehicles.

24-2. Functions. The cross-drive transmission provides hydraulic drive through a torque converter and contains the planetary gearing, steering mechanism, braking mechanism, and hydraulically operated clutches. The brakes are foot operated. The forward- and reverse-speed ranges and the steering are selected and hydraulically controlled from the driver's compartment. The transmission mounts crosswise in the vehicle and drives the two tracks through two flanges: the right output shaft flange and the left output shaft flange (right and left facing toward the front of the vehicle).

Section II. CONSTRUCTION AND OPERATION

24-3. General. There are several models of cross-drive transmissions. In general, this discussion will apply to all models of cross-drive transmissions except for the X1100-3B unit, which is covered in chapter 25. Reference should be made to the applicable technical manual whenever a detailed study of a particular cross-drive transmission is made. Figure 24-1 shows an external view of a cross-drive transmission, while figure 24-2 shows the main subassemblies in the transmission.

24-4. Torque Converter. The torque converter is a four-element (or four-member) converter similar to units described in paragraph 21-7. Note the location of the converter units in figure 24-3. The converter contains a pump and turbine plus two stators mounted on the converter ground sleeve by freewheeling clutches. Converter action is shown in figure 24-3. The pump drives the turbine through the medium of oil as described in paragraph 21-8. The stators reverse the direction of oil flow into a helping direction as it comes off the turbine vanes. Action is described below.

a. In the first converter phase (A, fig. 24-3), the stators are locked and the oil flow direction is reversed by the action of the two stators. The oil passes from the pump vanes, circulates through the turbine, two stators, and back to the pump.

b. In the second converter phase (B, fig. 24-3), the turbine has picked up speed and there is less torque multiplication. The oil leaves the turbine vanes at less of an angle and it begins to strike the back faces of the first stator vanes. The first stator thus begins to freewheel. In effect, it is simply moving out of the way. The second stator, however, still is needed to change the direction of oil flow.

c. In the coupling phase (C, fig. 24-3), the turbine and pump are revolving at nearly the same speed. The assembly acts like a fluid coupling. Both stators freewheel. Details of torque converter operation are found in paragraph 21-7.

d. The converter contains a lockup clutch that engages automatically when the transmission speed reaches a certain value. As this happens, the pump and turbine are locked together and rotate as a single unit. Power, therefore, is transmitted mechanically through the converter and no speed reduction or torque multiplication occurs.

24-5. Planetary Gearing in Gear Ranges.

a. General. The cross-drive transmission contains four planetary gear systems: the low-range planetary, the reverse-range planetary, and the two output planetaries. The low- and reverse-range planetaries are located in the right housing of the transmission (fig. 24-2). At each end of the cross-drive shaft is an output planetary that drives the output flanges. All the planetaries are similar, having four planet pinions and the usual sun gear and internal gear (also called ring

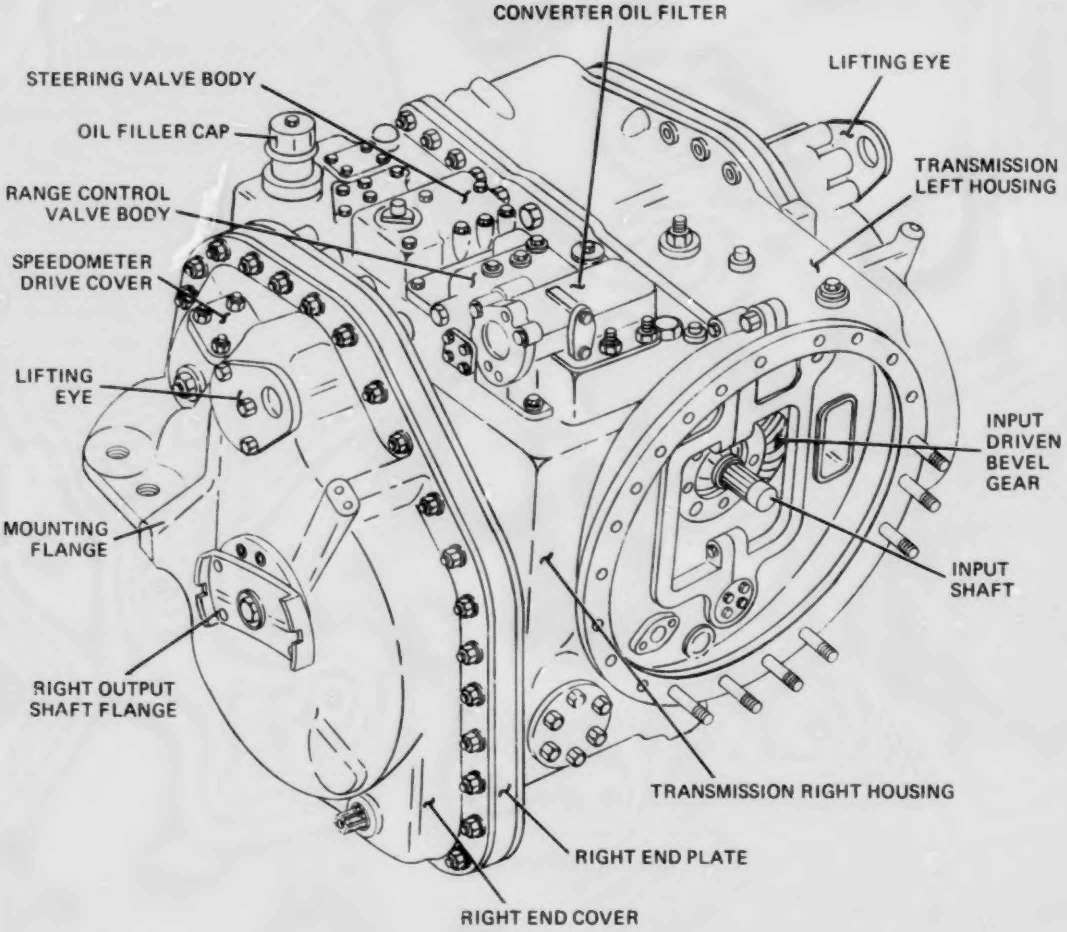

CONVERTER OIL FILTER
LIFTING EYE
STEERING VALVE BODY
OIL FILLER CAP
TRANSMISSION LEFT HOUSING
RANGE CONTROL VALVE BODY
SPEEDOMETER DRIVE COVER
LIFTING EYE
INPUT DRIVEN BEVEL GEAR
MOUNTING FLANGE
INPUT SHAFT
RIGHT OUTPUT SHAFT FLANGE
TRANSMISSION RIGHT HOUSING
RIGHT END PLATE
RIGHT END COVER

Figure 24-1. Cross-Drive Transmission – Right Front View.

gear). Operation of planetary gears is described in detail in paragraph 19-6.

b. Low Range. The low-range planetary provides an optional gear reduction through the transmission in addition to that provided by the other gearing. The low range may be selected by the driver when extra driving torque is required, as for instance, when pulling through heavy mud or sand. When the driver selects low range by operation of the control valve, oil pressure is directed to the low-range clutch. The clutch engages, thereby locking the low-range ring gear in a stationary position (fig. 24-4). The planet pinions are now forced to move around the ring gear, carrying with them the low-range planet carrier. The right output ring gear, to which the planet carrier is attached, turns with the carrier. This rotation is carried to the left output ring gear through the cross shaft, which is splined to both output ring gears. Both output ring gears, therefore, drive through their respective planetary gear systems to drive the two output flanges. Figure 24-4 illustrates the complete power flow path through the transmission. Note that the power passes through the converter first, then to the low-range sun gear, through the planet pinions, carrier, right output ring gear, cross shaft, and left output ring gear, and from the two output ring gears through the output planetaries to the output flanges.

c. High Range. For high-range operation, the driver places the control valve in high range. This action directs oil pressure to the high-range clutch, causing it to engage. This action locks together as a unit the high-range clutch housing, clutch hub, and the cross-drive shaft, making

TA233723

L 71

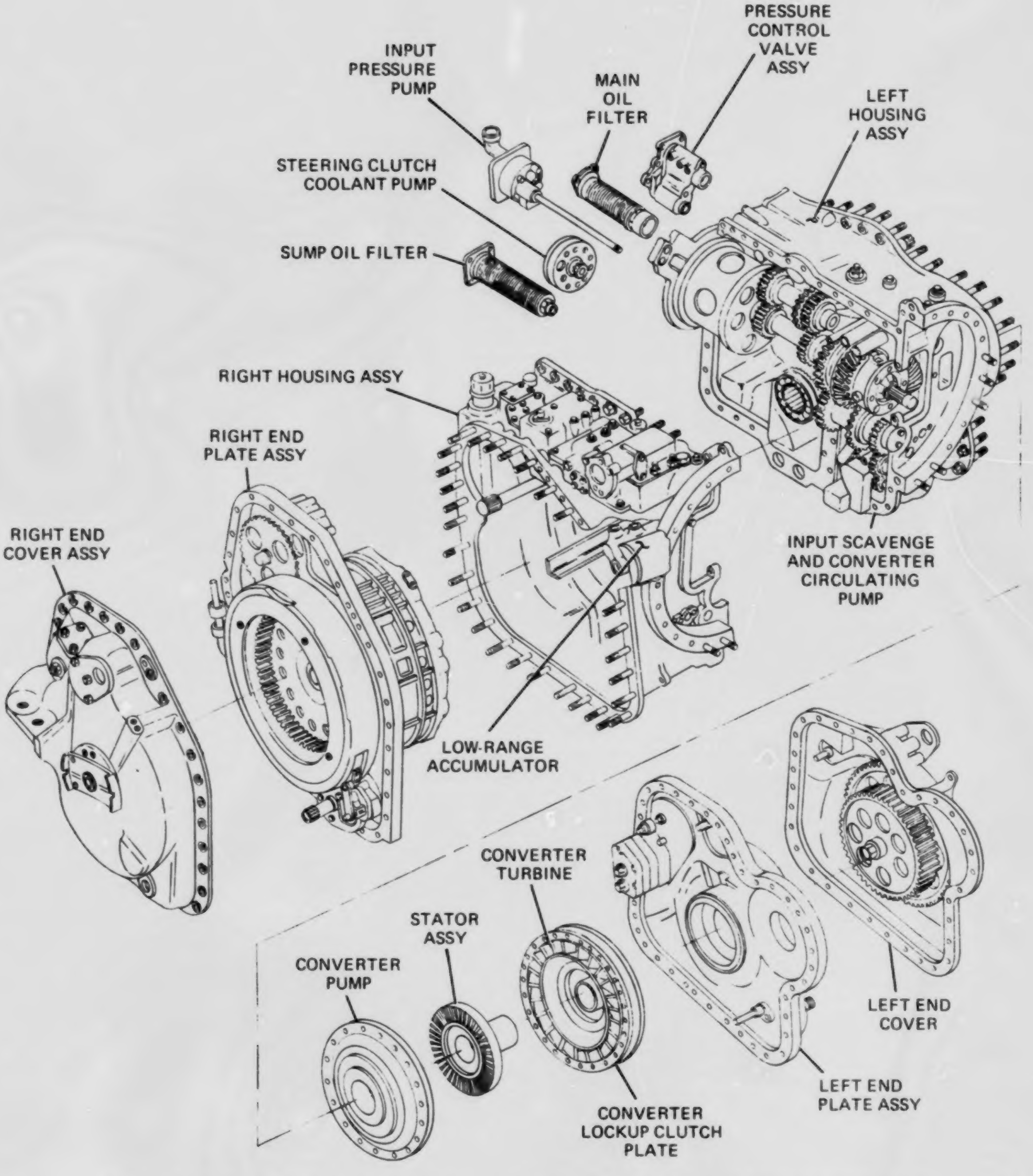
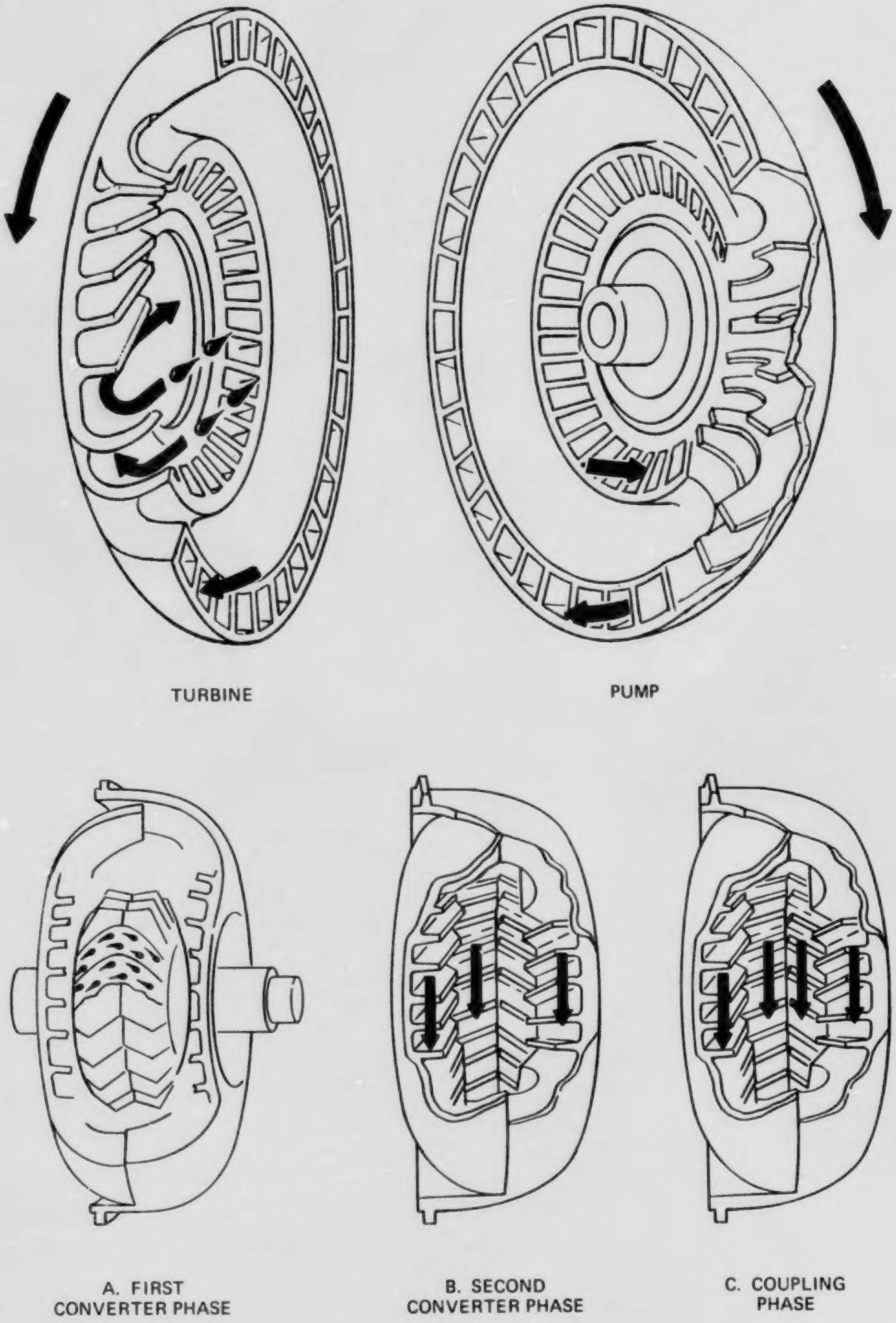

PRESSURE CONTROL VALVE ASSY
INPUT PRESSURE PUMP
MAIN OIL FILTER
LEFT HOUSING ASSY
STEERING CLUTCH COOLANT PUMP
SUMP OIL FILTER
RIGHT HOUSING ASSY
RIGHT END PLATE ASSY
RIGHT END COVER ASSY
INPUT SCAVENGE AND CONVERTER CIRCULATING PUMP
LOW-RANGE ACCUMULATOR
CONVERTER TURBINE
STATOR ASSY
CONVERTER PUMP
LEFT END COVER
LEFT END PLATE ASSY
CONVERTER LOCKUP CLUTCH PLATE

Figure 24-2. Cross-Drive Transmission – Disassembled into Main Subassemblies.

them all rotate at converter-turbine speed. Because the cross-drive shaft is splined to the output ring gears of the two output planetary gear systems, the two output planet carrier assemblies drive the output flanges. Figure 24-5 shows the power flow through the transmission in high range. The lockup clutch in the torque converter engages when a predetermined speed is reached in the transmission. Engagement of the lockup clutch locks the converter pump and turbine

TA233724

472


TURBINE

PUMP

A. FIRST CONVERTER PHASE

B. SECOND CONVERTER PHASE

C. COUPLING PHASE

Figure 24-3. Torque Converter Construction and Principles of Operation.

TA233725

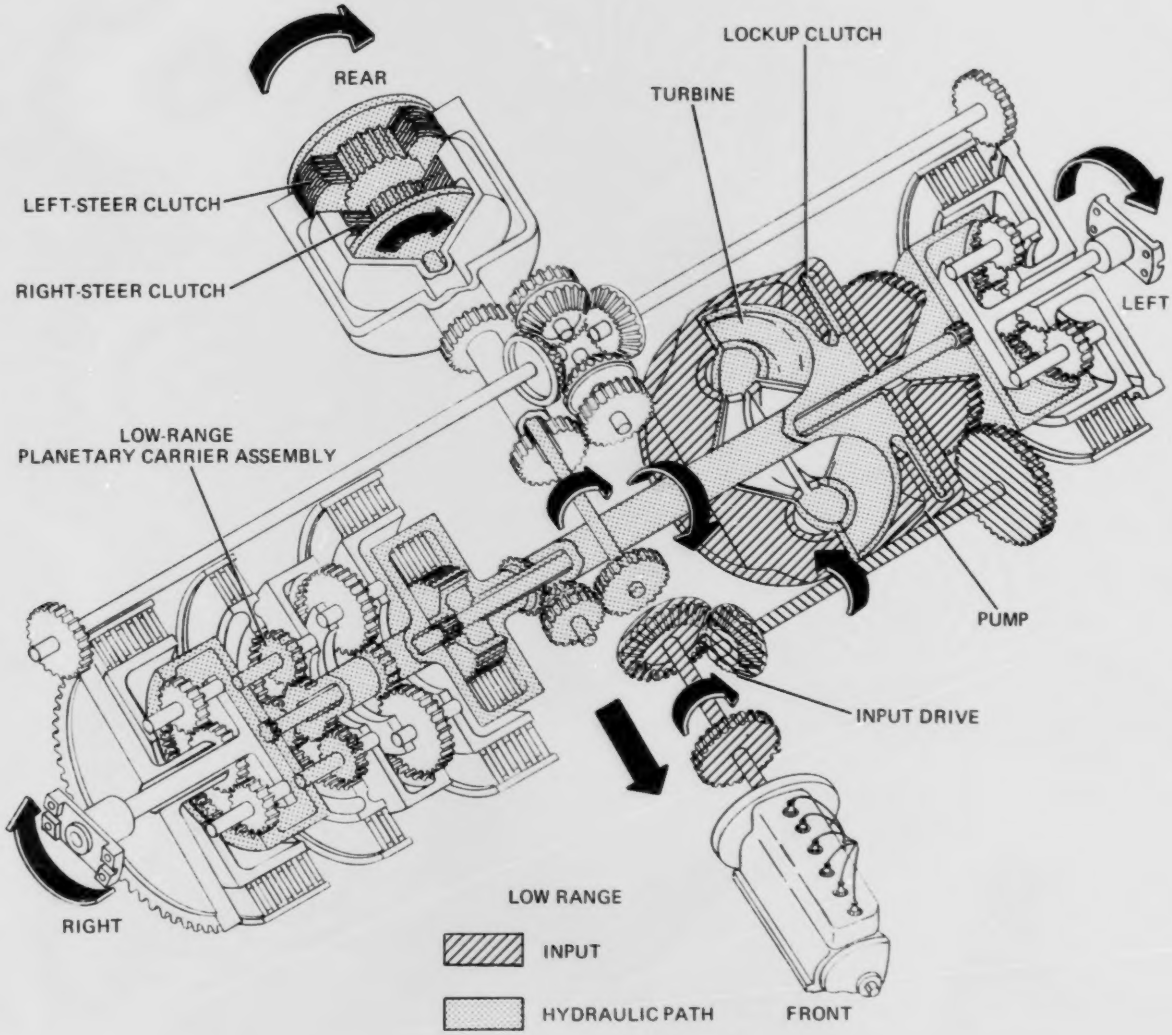

REAR
LOCKUP CLUTCH
TURBINE
LEFT-STEER CLUTCH
RIGHT-STEER CLUTCH
LEFT
LOW-RANGE PLANETARY CARRIER ASSEMBLY
PUMP
INPUT DRIVE
RIGHT
LOW RANGE
▨ INPUT
░ HYDRAULIC PATH
FRONT

Figure 24-4. Power Flow through Cross-Drive Transmission in Low Range. (Part A)

together so they turn as a unit and no hydraulic torque conversion occurs. Direct mechanical drive is delivered from the transmission input shaft, through the high-range clutch, to the transmission output. The power path is the same as that shown in figure 24-5, the only difference being that there is no speed reduction or torque increase in the torque converter.

d. Reverse Range. When the driver places the range control valve in reverse, oil pressure is directed to the reverse-range clutch, causing it to engage. The reverse-range clutch hub and reverse-range planet carrier are held stationary. This causes the reverse-range planet pinions to rotate in the direction shown in figure 24-6 as they are driven by the reverse-range sun gear. The reverse-range planet pinions, in turn, drive the reverse-range ring gear. Because the reverse-range ring gear is bolted to the right output ring gear (through the low-range planet carrier), the right output ring gear rotates. The cross-drive shaft, being splined to both the right output ring gear and the left output ring gear, carries the rotary motion to the left output ring gear so that both ring gears drive through their respective output planetary systems to drive the two output flanges. Note that the direction of rotation is reversed as compared to the two forward driving ranges (low and high) shown in

TA233726

471

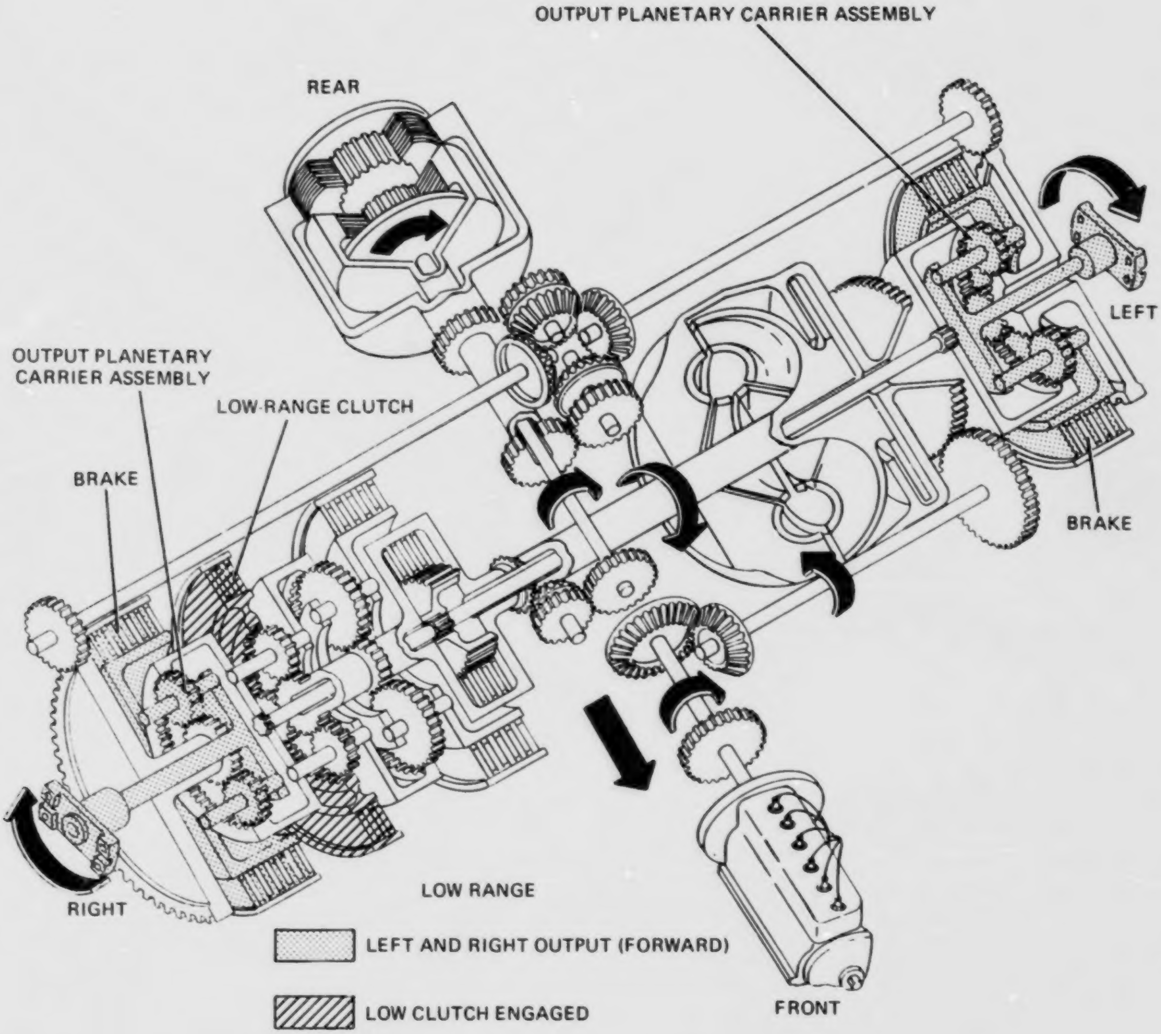

OUTPUT PLANETARY CARRIER ASSEMBLY
REAR
LEFT
OUTPUT PLANETARY CARRIER ASSEMBLY
LOW-RANGE CLUTCH
BRAKE
BRAKE
LOW RANGE
RIGHT
FRONT
▒ LEFT AND RIGHT OUTPUT (FORWARD)
▨ LOW CLUTCH ENGAGED

Figure 24-4. Power Flow through Cross-Drive Transmission in Low Range. (Part B)

figure 24-5. This reversal results because the reverse-range clutch holds the reverse-range planet carrier stationary as shown in figure 24-6.

24-6. Steering.

a. General. Steering is accomplished through the two steer clutches, the steer differential, and the gearing to the output planetary sun gears. Driving power is carried to the two steer clutches at all times by the gearing on the converter turbine output shaft. However, when neither of the steer clutches is engaged and the vehicle is moving straight ahead or straight reverse (both output flanges turning at the same speed and in same direction), no power is passing through the steering system. But when one of the steer clutches is engaged, power is carried through the steering system, and this causes the two sun gears in the two output planetaries to turn in opposite directions. As they turn in opposite directions, they provide opposing rotary motion to the output planetaries.

b. Left Steer in Neutral Range. Steering can be accomplished with the transmission in neutral; that is, with no power passing through the cross-drive shaft to the output planetaries. With this condition, the low-, high-, and reverse-range clutches are disengaged. No driving power

TA233727

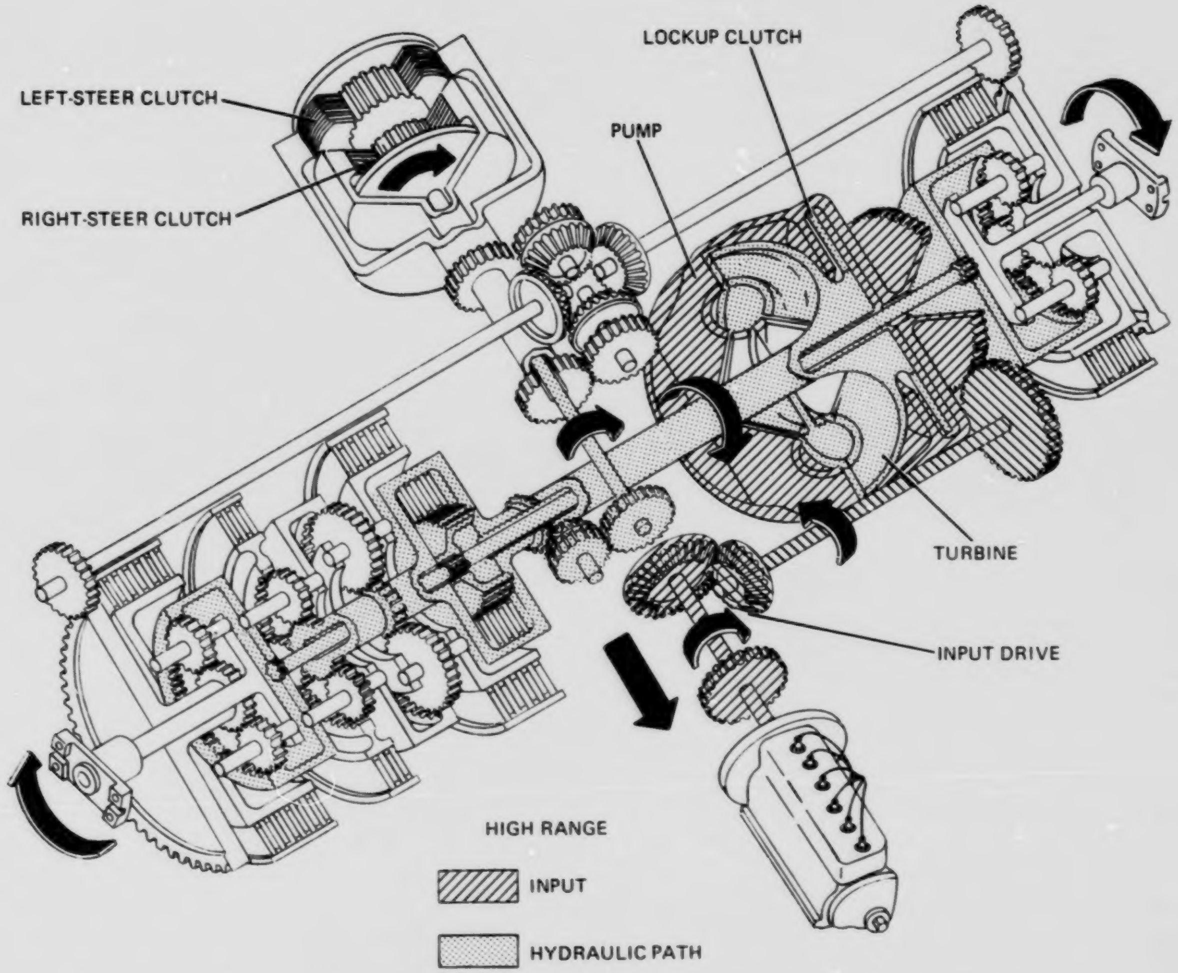


Figure 24-5. Power Flow through Cross-Drive Transmission in High Range. (Part A)

is being transmitted to the output ring gears. When the left steering valve is actuated by the driver for left steer, oil pressure is introduced into the left-steer-clutch piston, causing the left-steer clutch to engage. The clutch receives pressure proportional to the amount of steer applied, so that any variation from light to hard left steering will result. With the left-steer clutch engaged, the drive is from the turbine output shaft, through the left-steer clutch to the rear differential bevel gear. This bevel gear then drives the two engaged bevel gears in opposite directions, as shown in figure 24-7. These driven bevel gears, therefore, drive the two output sun gears in opposite directions. The output ring gears cannot turn in opposite directions because they are both splined to the cross-drive shaft. The output ring gears remain stationary and the two sun gears cause the planet pinions to rotate and move around the ring gears, thereby rotating the planet carriers. The right planet carrier rotates in a forward direction and the left planet carrier rotates in the reverse direction, as shown. This causes the right output flange to rotate in a forward direction and the left output flange to rotate in the reverse direction. Under the conditions described, which produce left steering, the vehicle pivots to the left.

c. Right Steer in Neutral Range. For right steer in neutral range, the low-, high-, and reverse-range clutches are disengaged and no driving power is being transmitted to the output ring gears. These are the same conditions as

TA233728

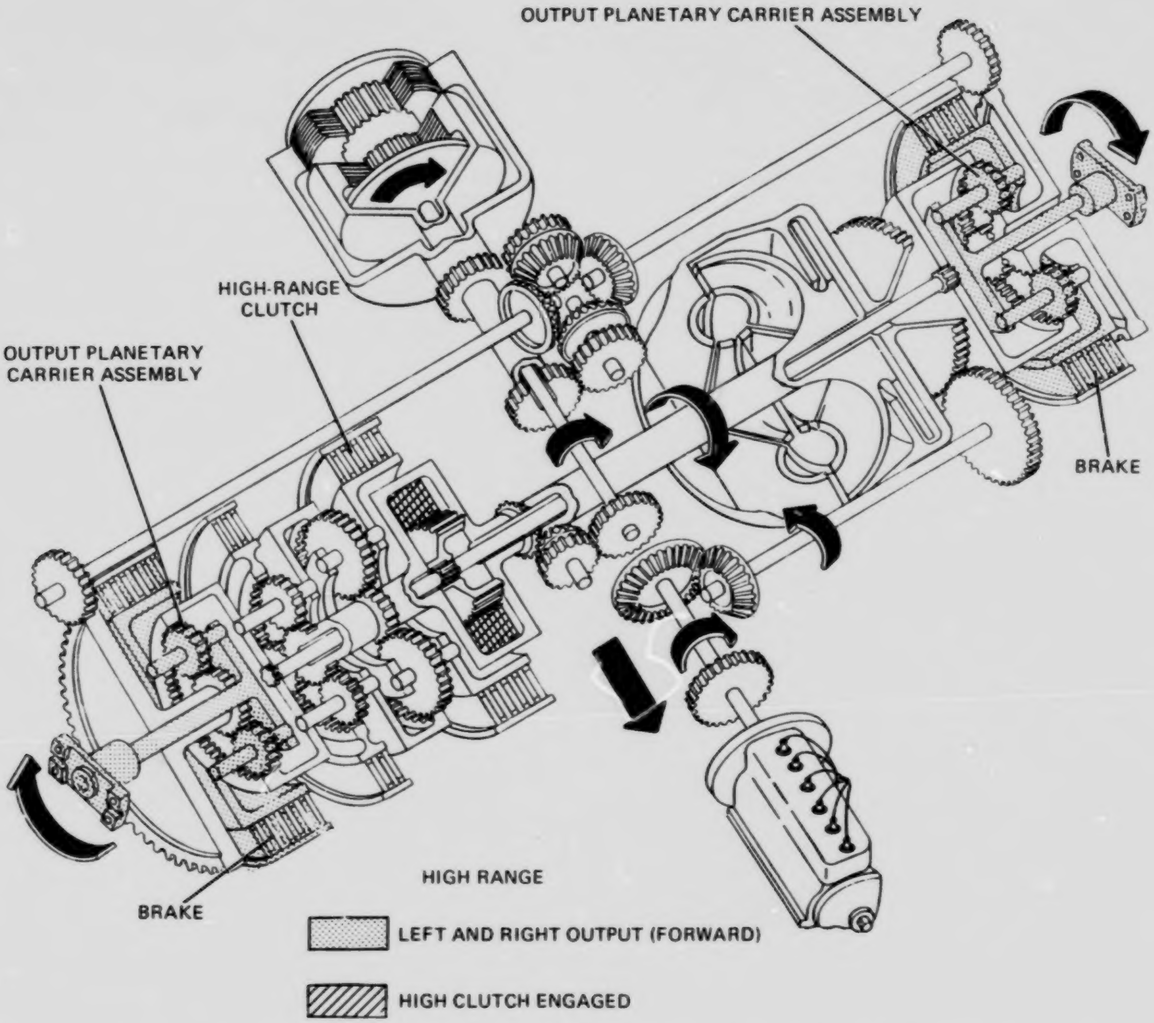

OUTPUT PLANETARY CARRIER ASSEMBLY
HIGH-RANGE CLUTCH
OUTPUT PLANETARY CARRIER ASSEMBLY
BRAKE
BRAKE
HIGH RANGE
░ LEFT AND RIGHT OUTPUT (FORWARD)
▨ HIGH CLUTCH ENGAGED

Figure 24-5. Power Flow through Cross-Drive Transmission in High Range. (Part B)

when a left steer in neutral range is being made. When the right steering valve is actuated by the driver for right steer, oil pressure is introduced into the right-steer-clutch piston, thereby causing the right-steer-clutch to engage as indicated in figure 24-8. As with left steering, the clutch receives pressure proportional to the amount of steering applied so that any variation from light to hard right steering will result. With the right-steer clutch engaged, the drive is from the turbine output shaft, through the right-steer clutch to the differential front bevel gear. This bevel gear then drives the two engaged bevel gears in opposite directions as shown in figure 24-8. Notice that these two bevel gears are turning in directions that are the reverse of those shown in figure 24-7. The two bevel gears drive the two output sun gears in opposite directions as shown, causing the right output flange to rotate in a reverse direction and the left output flange to rotate in a forward direction so that the vehicle pivots to the right.

d. Left Steer in Low Range. In low range, the output ring gears are driving the output planet carriers forward so that both output flanges are rotating in a forward direction. When the left steering valve is actuated by the driver for left steering, oil pressure is directed to the left-steer-clutch piston, engaging the left-steer clutch (fig. 24-9). The clutch receives pressure proportional to the amount of steer applied. When the left-steer clutch engages, driving power is

TA233729

477

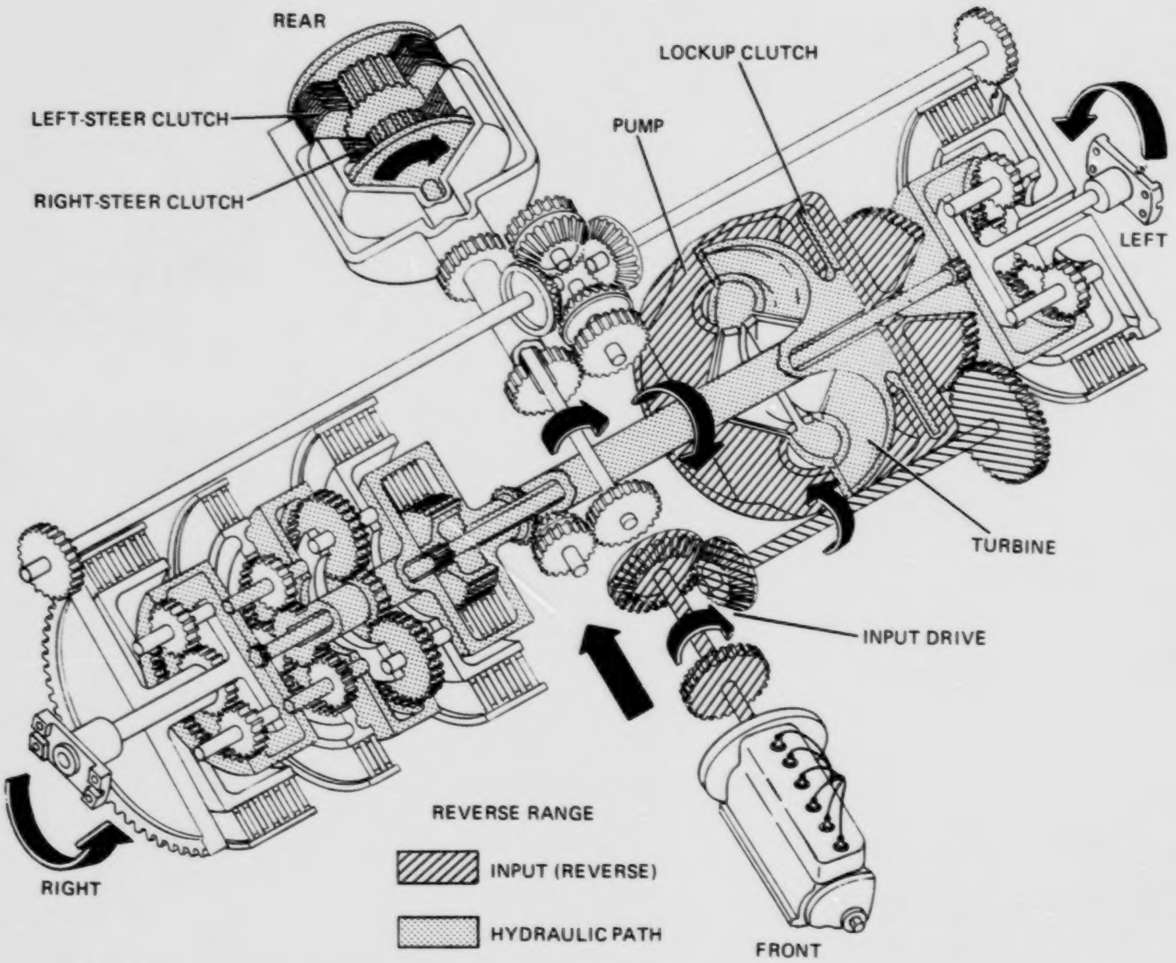


Figure 24-6. Power Flow through Cross-Drive Transmission in Reverse Range. (Part A)

applied to the rear differential bevel gear. This bevel gear then drives the two engaged bevel gears in opposite directions exactly as in left steer in neutral range (fig. 24-7). This gives a forward rotation to the right output sun gear and a reverse rotation to the left output sun gear. Because both output ring gears are rotating forward, the forward rotation of the right output sun gear will increase the rotary speed of the right output planet carrier and the right output flange. At the same time, the reverse rotation of the left output sun gear will reduce the rotary speed of the left output planet carrier and the left output flange. At the same time, the reverse rotation of the left output sun gear will reduce the rotary speed of the left output planet carrier and the left output flange. With the right output speeded up and the left output slowed down, the vehicle steers to the left.

e. Right Steer in Low Range. Right steer in low range is very similar to left steer in low range. The only difference is that, in right steer, the right-steer clutch is engaged (fig. 24-9), so that the differential front bevel gear drives the two engaged bevel gears. This gives the right output sun gear a reverse rotation and the left output sun gear a forward rotation. Because both output ring gears are rotating forward, the forward rotation of the left output sun gear will increase the rotary speed of the left output planet carrier and the left output flange. At the same time, the reverse rotation of the right output sun gear will reduce the rotary speed of the right output planet carrier and the right output flange. With the right output

TA233730

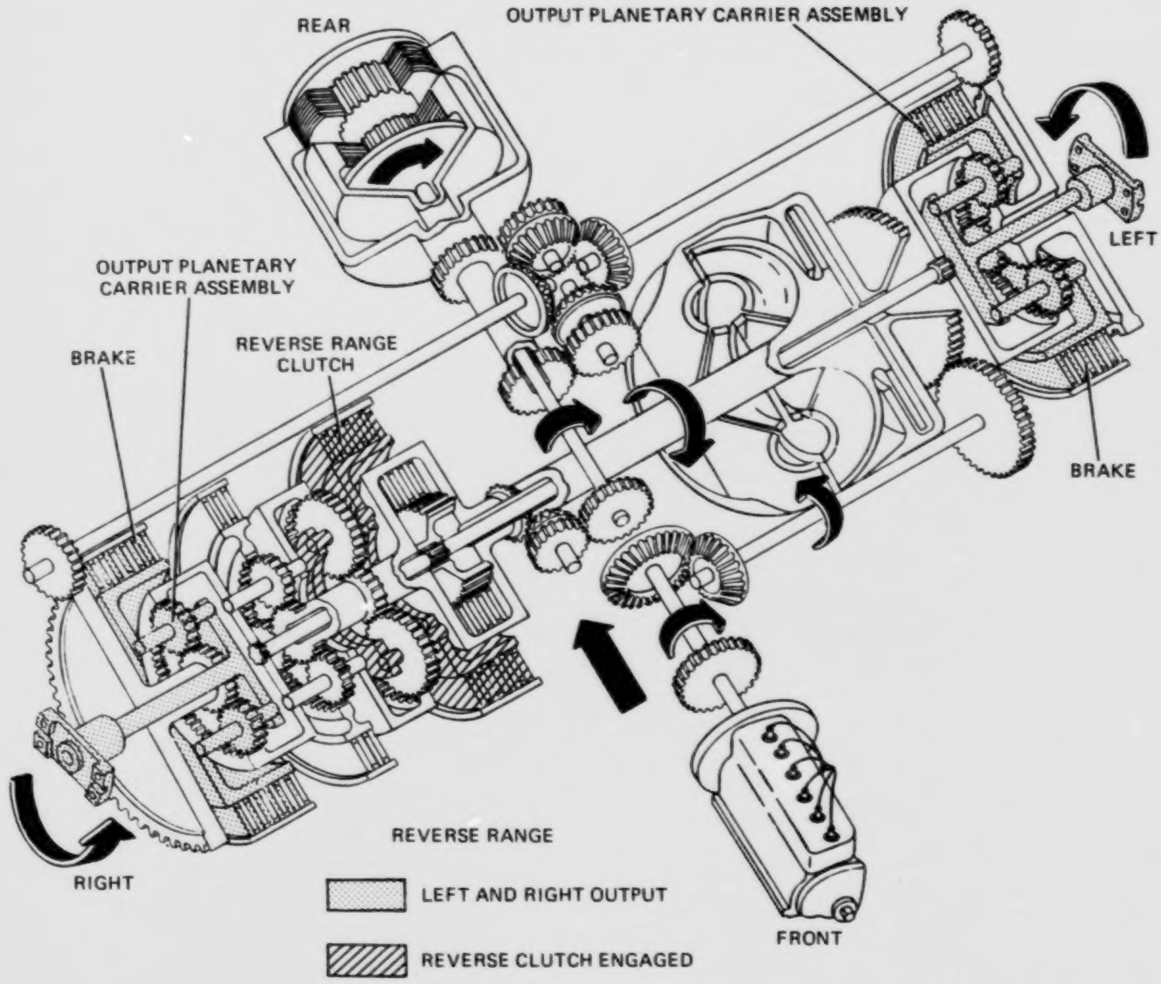

REAR
OUTPUT PLANETARY CARRIER ASSEMBLY
LEFT
OUTPUT PLANETARY CARRIER ASSEMBLY
BRAKE
REVERSE RANGE CLUTCH
BRAKE
RIGHT
REVERSE RANGE
░ LEFT AND RIGHT OUTPUT
▨ REVERSE CLUTCH ENGAGED
FRONT

Figure 24-6. Power Flow through Cross-Drive Transmission in Reverse Range. (Part B)

TA233731

slowed down and the left output speeded up, the vehicle steers to the right.

f. Right and Left Steer in High Range. Right steer and left steer in high range are identical to right steer and left steer in low range, except that the transmission is in high range (fig. 24-5).

g. Right and Left Steer in Reverse Range. Right steer and left steer in reverse range are identical to right steer and left steer in low range or in high range, except that the transmission is in reverse range (fig. 24-6).

24-7. Hydraulic System.

a. General. The hydraulic system and the lubrication system use the same oil, operating from a common oil reservoir in the transmission. The oil also circulates through a cooling radiator and helps prevent excessive temperatures in the transmission. The radiator has separate cores for each. Actually, there are two separate radiators, one on each side of the engine, in the application shown. Each has separate cores for engine and transmission oil. The hydraulic system uses two separate valve systems for range and steering control.

b. Range Control Valve (Fig. 24-10). The range control valve consists essentially of a cylinder with a series of ports and a cylindrical valve that can be shifted into various positions by operation of the control lever in the driving

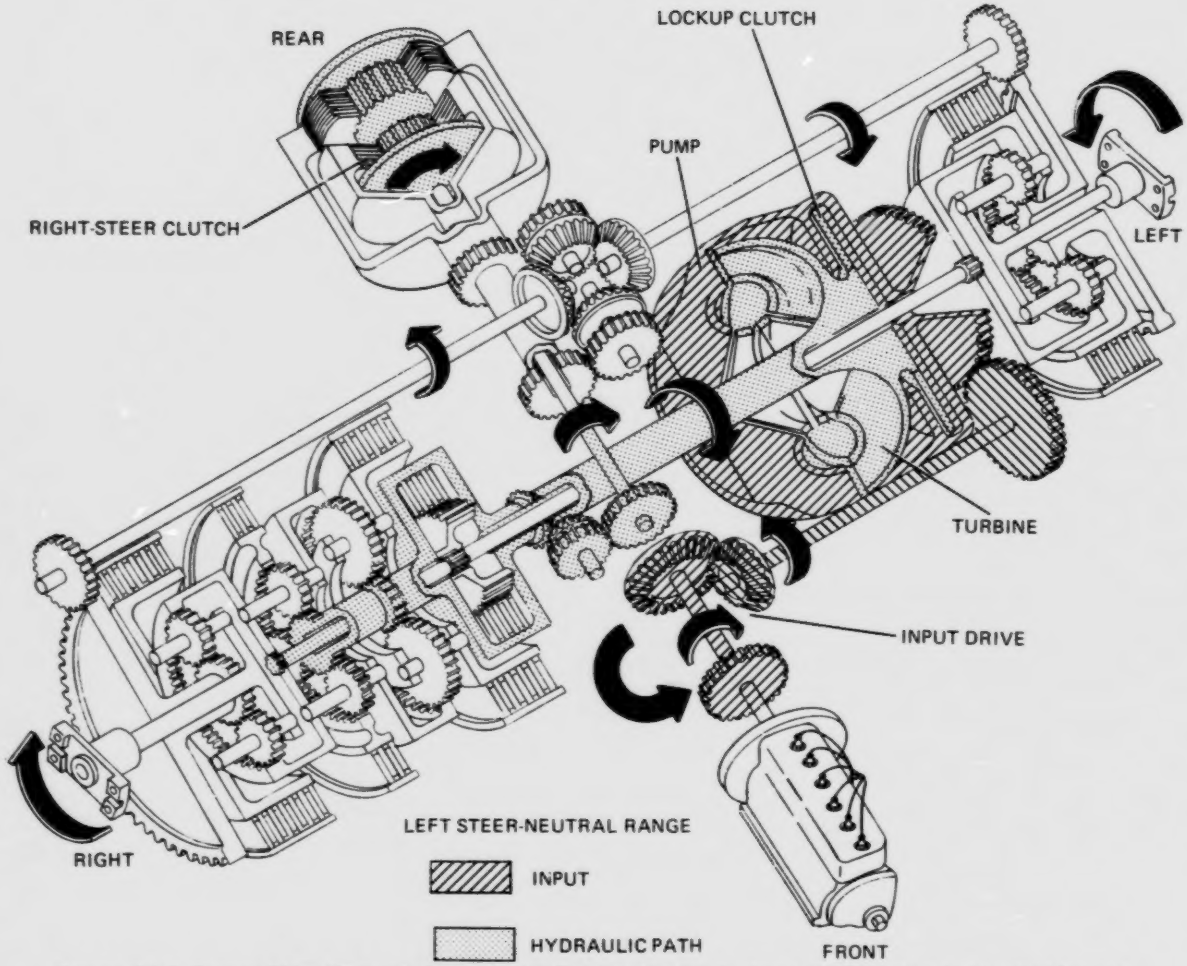


Figure 24-7. Power Flow through Cross-Drive Transmission during Left Steering in Neutral Range. (Part A)

compartment. When the valve is shifted, various ports are uncovered so that oil pressure is admitted, through the oil lines, to the different clutches. Oil pressure cannot be directed to more than one clutch at a time. In neutral, oil pressure is cut off from the low-range clutch, high-range clutch, and reverse-range clutch so that there is no drive to the output ring gears. However, steering in neutral range can be accomplished by operation of the steering valves as described below.

c. Low Range (Fig. 24-10). When the range-control valve is shifted to low range, oil pressure is admitted to the low-range clutch (through line 18). Oil pressure is cut off from the other range clutches. The low-range clutch engages and the power flow through the transmission is as shown in figure 24-4. Note that the low-range line also is connected to a low-range accumulator (through line 19). The accumulator is a spring-loaded piston in a cylinder. The piston moves to compress the spring as oil pressure is admitted into the low-range clutch line. This provides a cushioning effect and softens the engagement of the low-range clutch, thereby preventing a sudden and jolting shift.

d. High Range (Fig. 24-10). When the range-control valve is shifted to high range, oil pressure is admitted to the high-range clutch (through line 17). Oil pressure is cut off from the other range clutches. The high-range clutch therefore engages, and the power flow through the transmission is as shown in figure 24-5.

TA233732

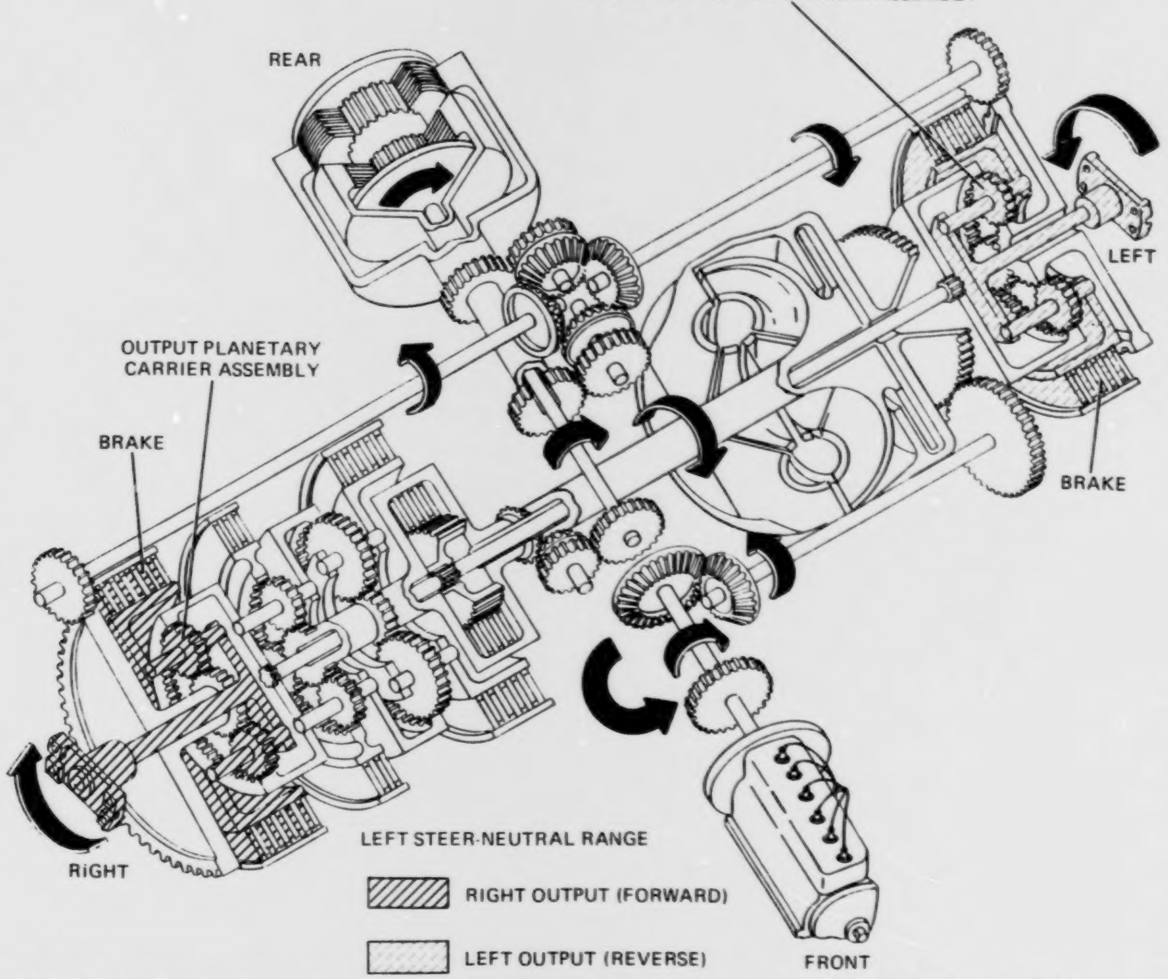

OUTPUT PLANETARY CARRIER ASSEMBLY
REAR
LEFT
OUTPUT PLANETARY CARRIER ASSEMBLY
BRAKE
BRAKE
RIGHT
LEFT STEER-NEUTRAL RANGE
▨ RIGHT OUTPUT (FORWARD)
☐ LEFT OUTPUT (REVERSE)
FRONT

Figure 24-7. Power Flow through Cross-Drive Transmission during Left Steering in Neutral Range. (Part B)

e. Reverse Range (Fig. 24-10). When the range-control valve is shifted to reverse range, oil pressure is admitted to the reverse-range clutch (through line 20). Oil pressure is cut off from the other range clutches. The reverse-range clutch therefore engages, and the power flow through the transmission is as shown in figure 24-6.

f. Steering Valves (Fig. 24-10). The right- and left-steering valves (1 and 2) are operated by linkage from the driver's compartment. These valves are modulating-type valves, which means they are not simple open-or-closed valves but can be opened to admit more or less oil pressure to the steer clutches. The driver can vary the oil pressure to the steer clutches by varying the amount of pressure applied to the steering control. This, in turn, varies the amount of steering obtained. When a left steer is applied to the control, the left-steering valve admits oil pressure to the left-steer clutch to produce a left steer; the power flow through the transmission steering system being as shown in figures 24-7 and 24-9. When a right steer is applied to the control by the driver, the right-steering valve admits oil pressure to the right-steer clutch to produce a right steer.

g. Pressure Regulating Valves (Fig. 24-10). The range control valve body also contains

TA233733

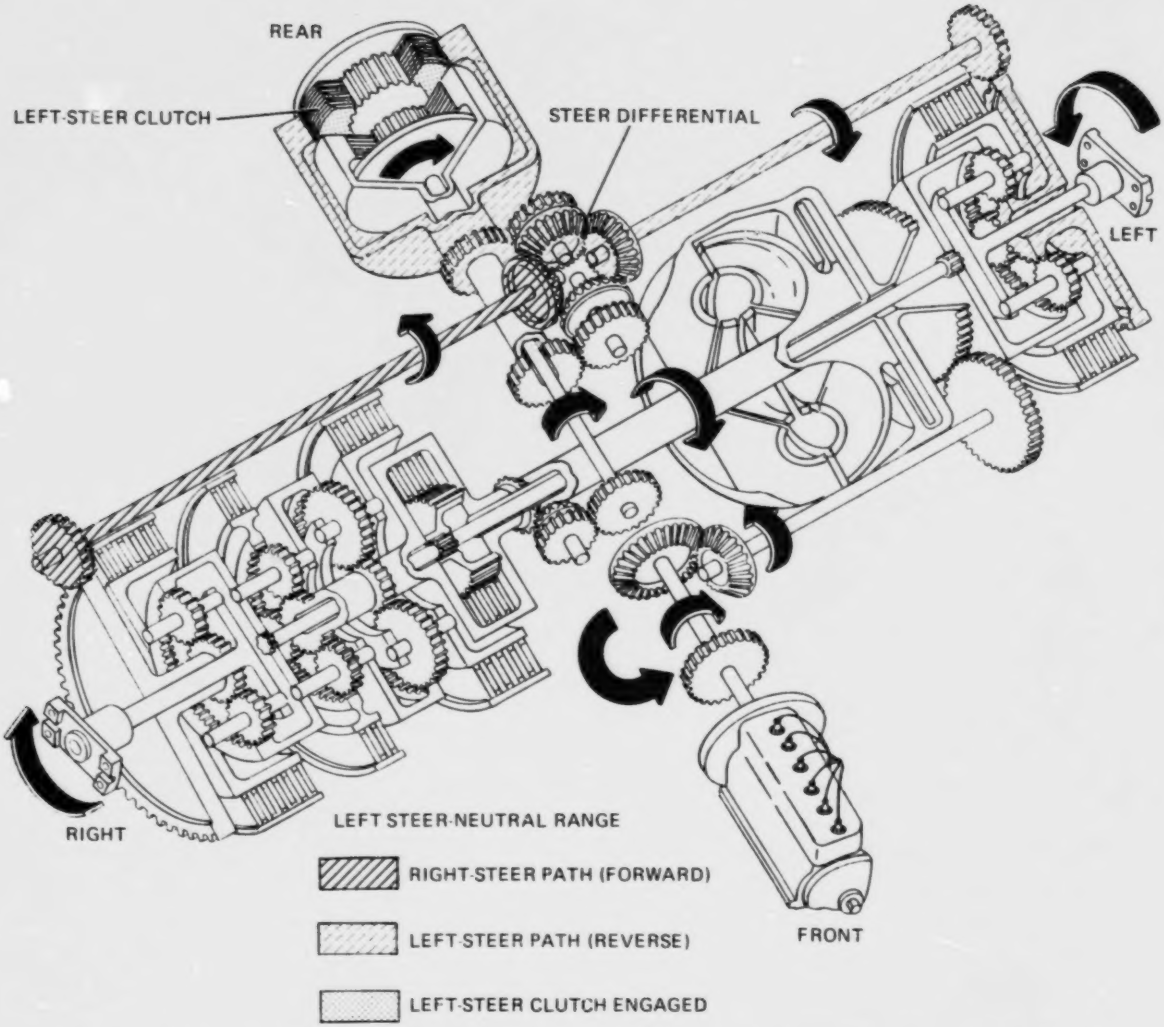

REAR
LEFT-STEER CLUTCH
STEER DIFFERENTIAL
LEFT
RIGHT
FRONT
LEFT STEER-NEUTRAL RANGE
▨ RIGHT-STEER PATH (FORWARD)
▨ LEFT-STEER PATH (REVERSE)
░ LEFT-STEER CLUTCH ENGAGED

Figure 24-7. Power Flow through Cross-Drive Transmission during Left Steering in Neutral Range. (Part C)

various pressure regulating valves. Main pressure from the oil pump is admitted to the valve body through line (15). The main-pressure regulator valve (16) prevents excessive pressure while the main-pressure relief valve (14) opens to permit excessive oil to flow back to the oil reservoir. Oil pressure to the converter is regulated by valve (6) while oil pressure to the lubrication system is regulated by valve (7). Valve (11) is a cooler bypass valve that bypasses oil from the lubrication system and is not needed to maintain pressure. Valve (3) is a steering-overspeed safety valve that prevents excessive pressure to the steer clutches that would result in rapid steering.

24-8. Braking. Each of the two output planetary systems includes a friction disk brake assembly (fig. 24-11). Each assembly consists of six internally splined disks splined to the output planet carrier and five externally splined disks splined to the brake anchor. The brake anchor is bolted to the transmission end plate and, therefore, is stationary. Inside the brake anchor is a brake-apply cam-stationary ring. Next to the stationary ring is a brake-apply cam-rotating ring. A single brake pedal in the driver's compartment applies both brakes at the same time. When a brake is applied, mechanical linkage causes the brake-apply shaft to rotate. This causes the

TA233734

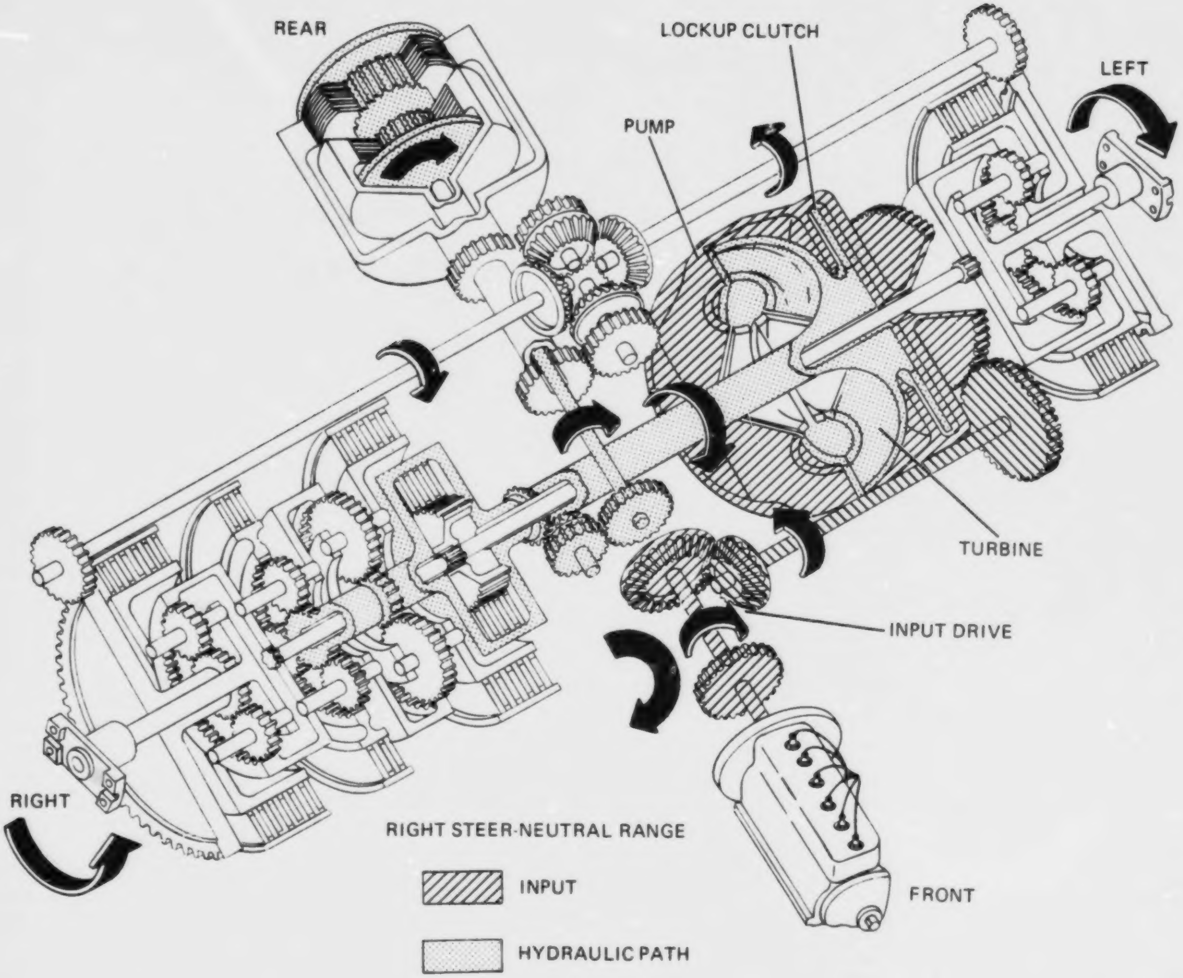

REAR
LOCKUP CLUTCH
LEFT
PUMP
TURBINE
INPUT DRIVE
RIGHT
RIGHT STEER-NEUTRAL RANGE
▨ INPUT
HYDRAULIC PATH
FRONT

Figure 24-8. Power Flow through Cross-Drive Transmission during Right Steering in Neutral Range. (Part A)

brake-apply cam-rotating ring to rotate a few degrees, forcing the 12 brake-apply balls to roll up grooved ramps. Because these ramps are located between the two cam rings, the balls force the two rings apart. The stationary ring, being fastened to the anchor plate, cannot move, so the rotating ring must move. This movement compresses the disk pack through the brake-apply ring, thereby applying the brake. The same action takes place on both assemblies. When the brakes are released, the brake-apply mechanism rotates the rotating ring back to its original position so the pressure on the disk pack is relieved.

TA233735

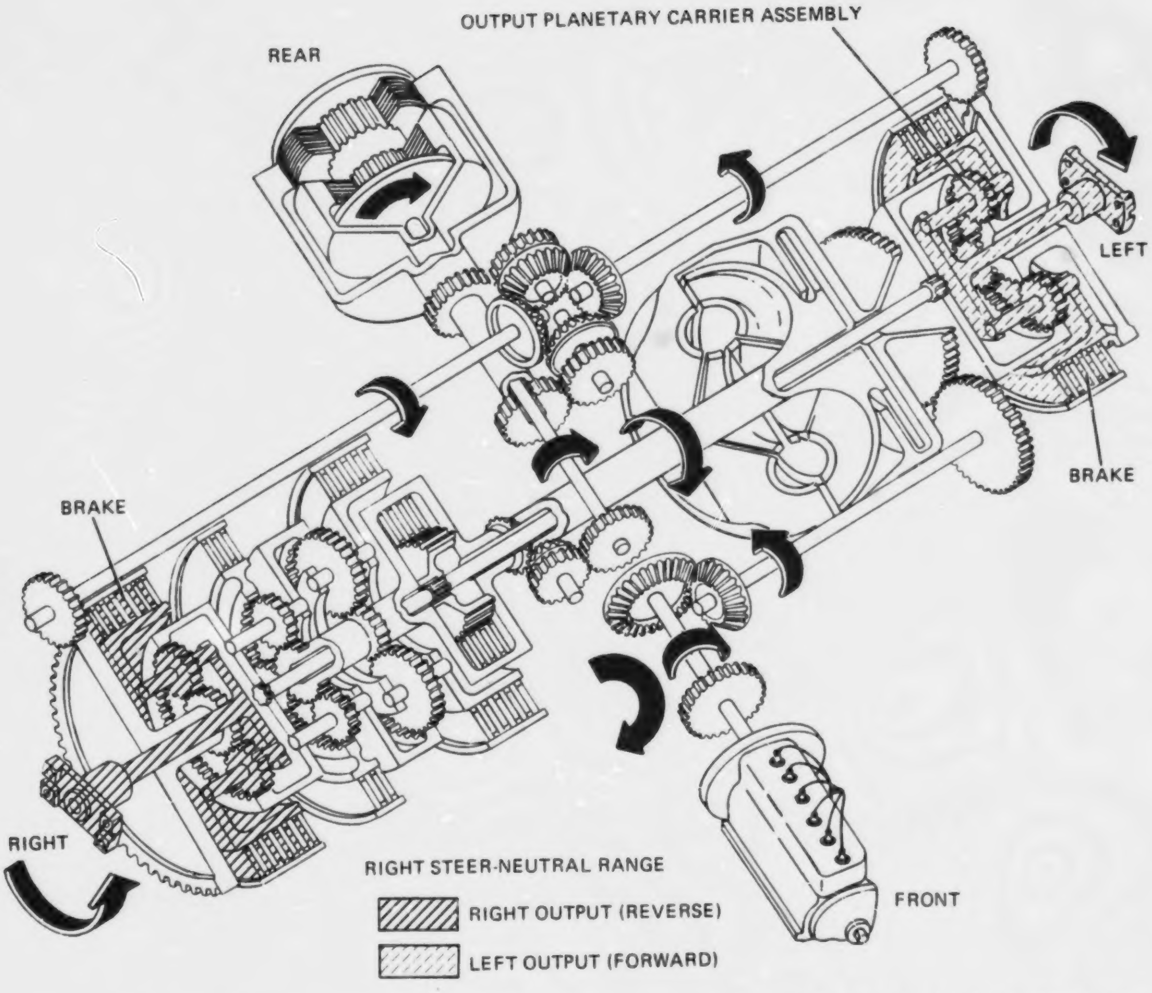

OUTPUT PLANETARY CARRIER ASSEMBLY
REAR
LEFT
BRAKE
BRAKE
RIGHT
FRONT
RIGHT STEER-NEUTRAL RANGE
▨ RIGHT OUTPUT (REVERSE)
░ LEFT OUTPUT (FORWARD)

Figure 24-8. Power Flow through Cross-Drive Transmission during Right Steering in Neutral Range. (Part B)

TA233736

482

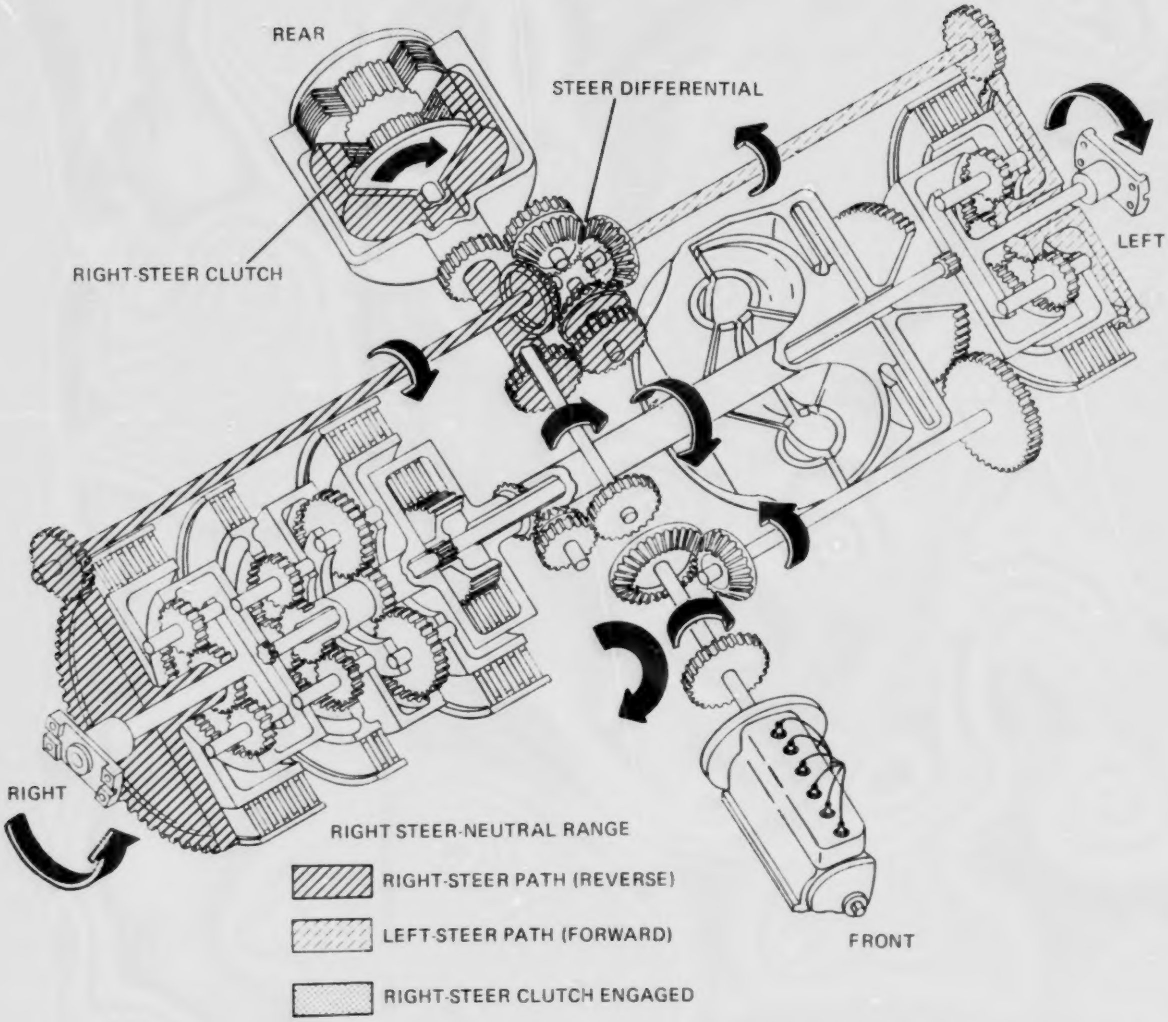

REAR
STEER DIFFERENTIAL
RIGHT-STEER CLUTCH
LEFT
RIGHT
FRONT
RIGHT STEER-NEUTRAL RANGE
▨ RIGHT-STEER PATH (REVERSE)
▨ LEFT-STEER PATH (FORWARD)
▒ RIGHT-STEER CLUTCH ENGAGED

Figure 24-8. Power Flow through Cross-Drive Transmission during Right Steering in Neutral Range. (Part C)

TA233737

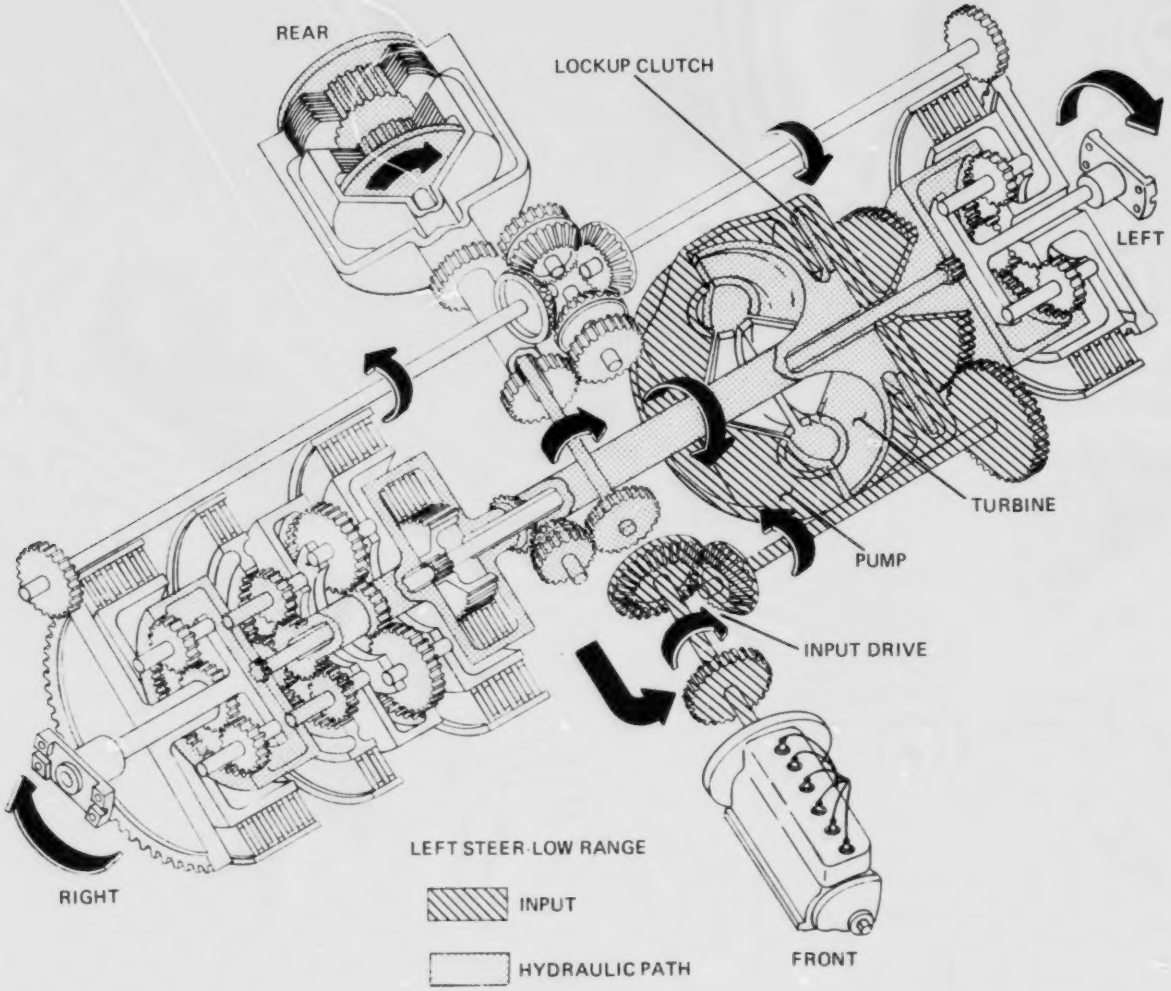

REAR
LOCKUP CLUTCH
LEFT
TURBINE
PUMP
INPUT DRIVE
RIGHT
FRONT
LEFT STEER-LOW RANGE
▨ INPUT
☐ HYDRAULIC PATH

Figure 24-9. Power Flow through Cross-Drive Transmission during Left Steering in Low Range. (Part A)

TA233738

486

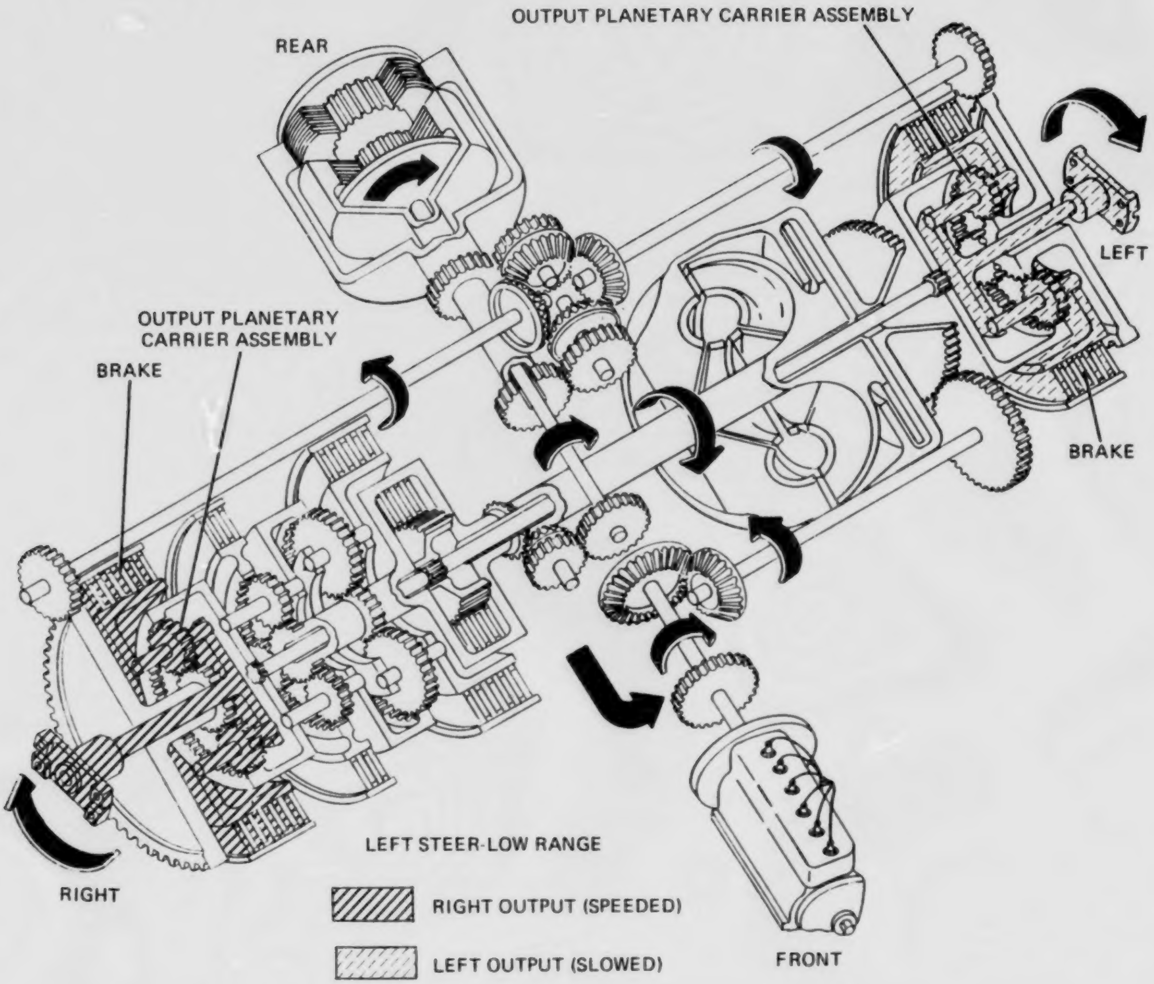

OUTPUT PLANETARY CARRIER ASSEMBLY
REAR
LEFT
OUTPUT PLANETARY CARRIER ASSEMBLY
BRAKE
BRAKE
LEFT STEER-LOW RANGE
RIGHT
▨ RIGHT OUTPUT (SPEEDED)
▨ LEFT OUTPUT (SLOWED)
FRONT

Figure 24-9. Power Flow through Cross-Drive Transmission during Left Steering in Low Range. (Part B)

TA233739

487

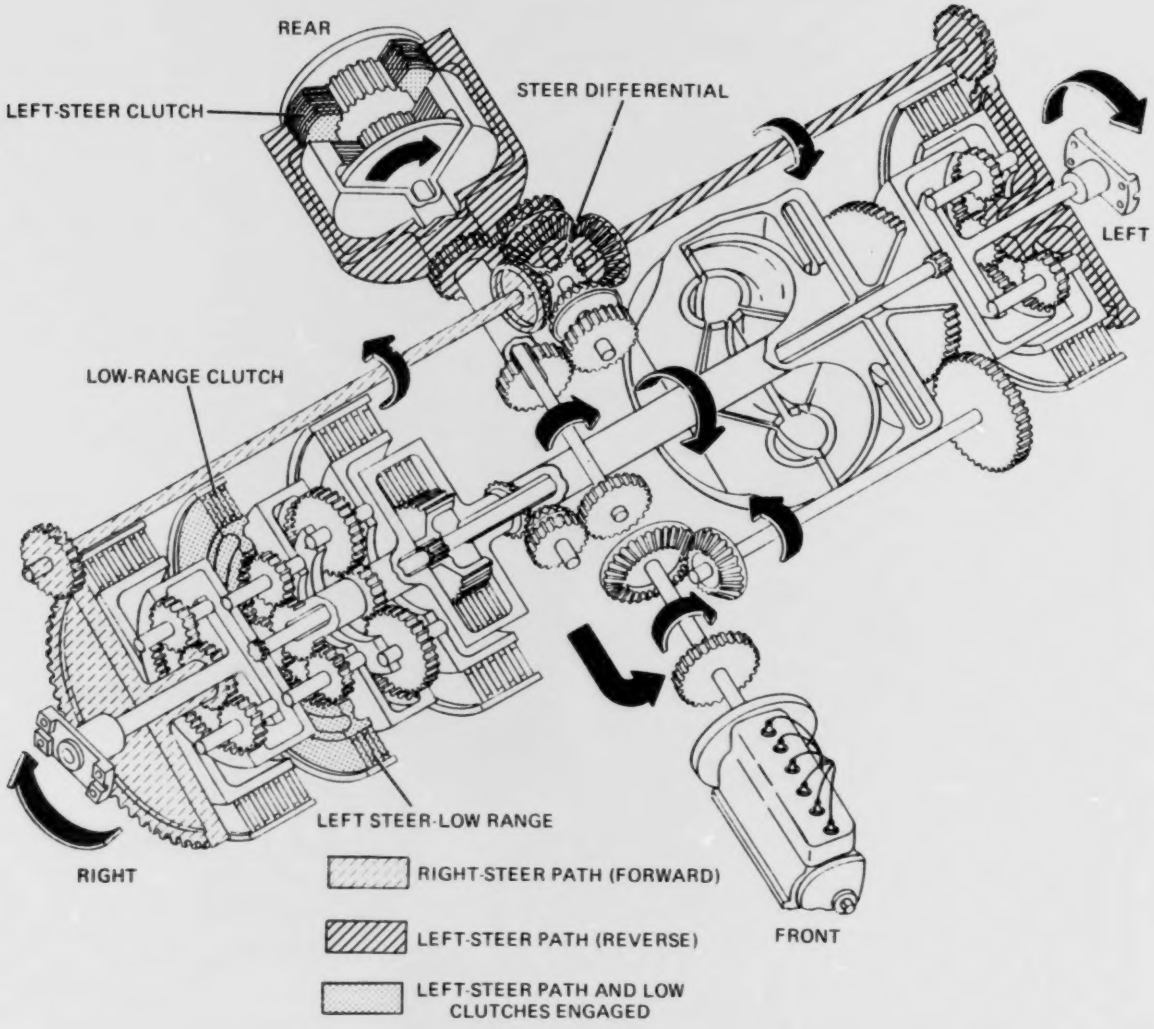
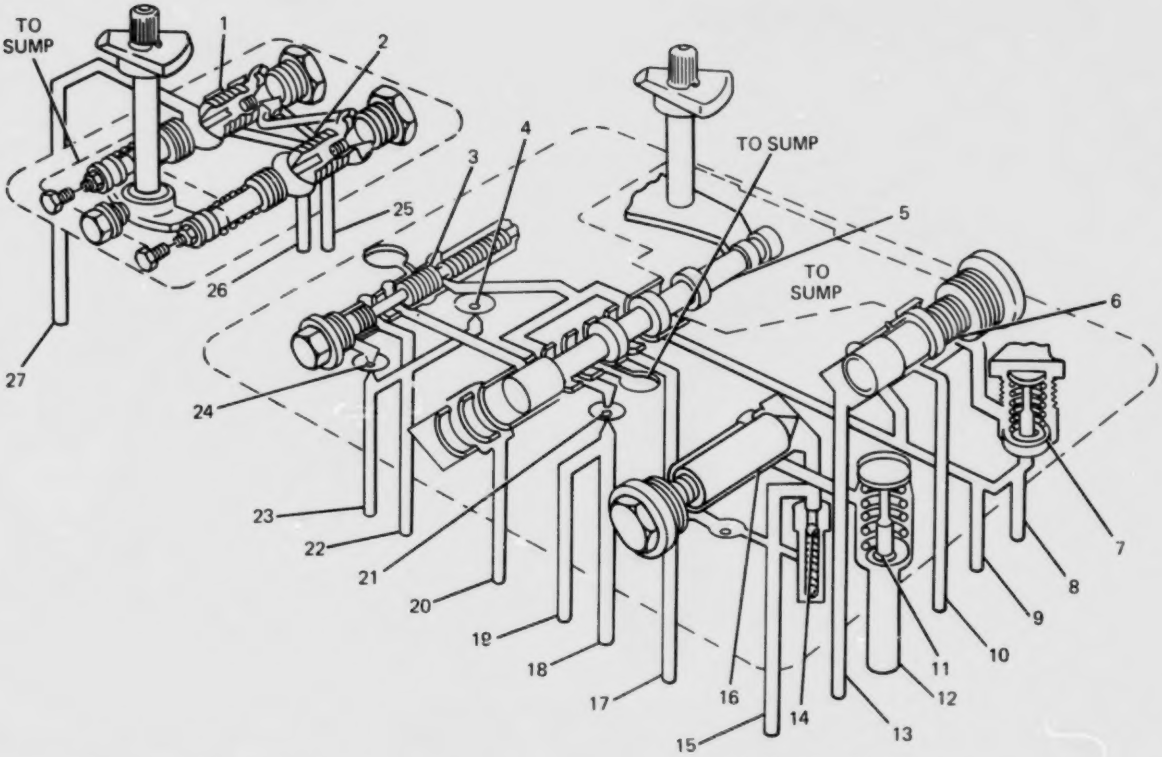

REAR
LEFT-STEER CLUTCH
STEER DIFFERENTIAL
LEFT
LOW-RANGE CLUTCH
LEFT STEER-LOW RANGE
RIGHT
FRONT
RIGHT-STEER PATH (FORWARD)
LEFT-STEER PATH (REVERSE)
LEFT-STEER PATH AND LOW CLUTCHES ENGAGED

Figure 24-9. Power Flow through Cross-Drive Transmission during Left Steering in Low Range. (Part C)

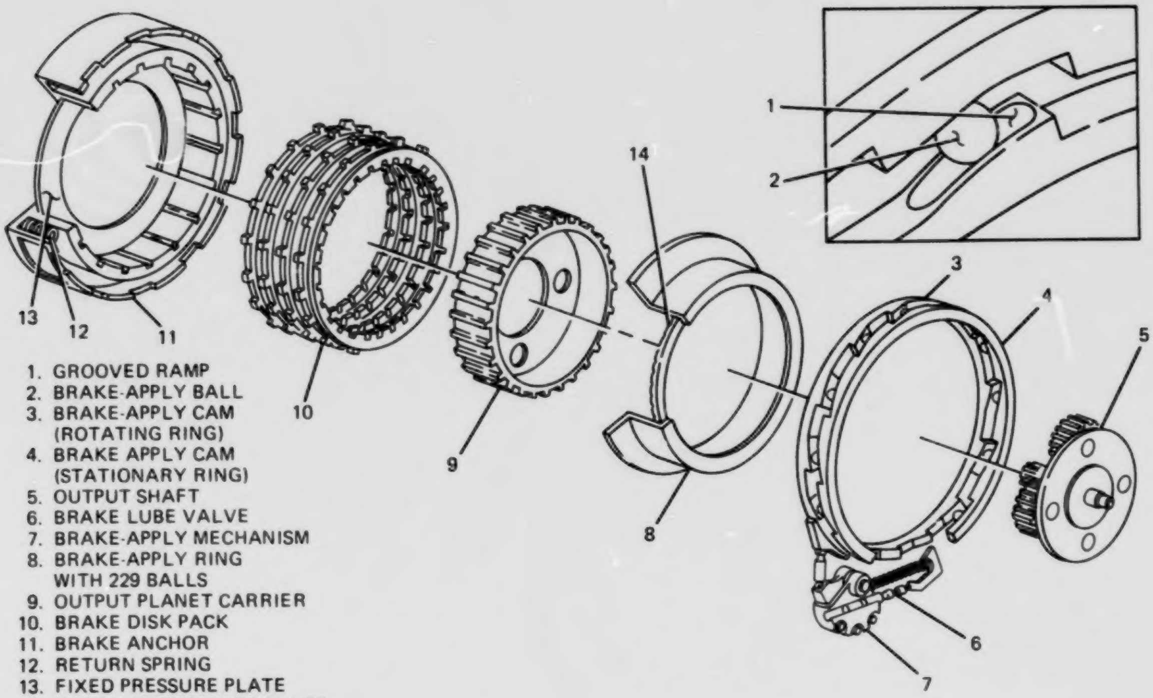
TA233740



1. RIGHT-STEERING VALVE
2. LEFT-STEERING VALVE
3. STEERING-OVERSPEED SAFETY VALVE
4. ORIFICE
5. RANGE CONTROL VALVE
6. CONVERTER-PRESSURE REGULATOR VALVE
7. LUBRICATION REGULATOR VALVE
8. TO LUBRICATING SYSTEM
9. TO STEERING-OVERSPEED LIMIT PUMP
10. TO CONVERTER LOCKUP CLUTCH
11. COOLER BYPASS VALVE
12. FROM CONVERTER
13. TO CONVERTER
14. MAIN-PRESSURE RELIEF VALVE
15. MAIN PRESSURE
16. MAIN-PRESSURE REGULATOR VALVE
17. TO HIGH-RANGE CLUTCH
18. TO LOW-RANGE CLUTCH
19. TO LOW-RANGE ACCUMULATOR
20. TO REVERSE-RANGE CLUTCH
21. LOW-RANGE ORIFICE
22. MAIN PRESSURE
23. FROM STEERING-OVERSPEED LIMIT PUMP
24. ORIFICE
25. MAIN PRESSURE
26. TO LEFT-STEERING CLUTCH
27. TO RIGHT-STEERING CLUTCH

Figure 24-10. Range Control Valve and Steering Control Valve Schematic Diagram.

TA233741



1. GROOVED RAMP
2. BRAKE-APPLY BALL
3. BRAKE-APPLY CAM (ROTATING RING)
4. BRAKE APPLY CAM (STATIONARY RING)
5. OUTPUT SHAFT
6. BRAKE LUBE VALVE
7. BRAKE-APPLY MECHANISM
8. BRAKE-APPLY RING WITH 229 BALLS
9. OUTPUT PLANET CARRIER
10. BRAKE DISK PACK
11. BRAKE ANCHOR
12. RETURN SPRING
13. FIXED PRESSURE PLATE
14. FLOATING PRESSURE PLATE

Figure 24-11. Brake – Schematic View.

TA233742

CHAPTER 25

X1100 SERIES CROSS-DRIVE TRANSMISSION

Section I. FUNCTION

25-1. General. The X1100-3B, a cross-drive transmission, features a hydraulic torque converter combined with a series of planetary gear packages for propulsion, a hydrostatic pump and motor unit with combining planetaries for differential steering control, and integral power-assisted brakes. Different input modules are used with the respective engine to increase versatility.

25-2. Function. The X1100-3B transmission provides hydraulic drive through a locking torque converter. The transmission offers four forward speeds and two reverse speeds with fully automatic shifting and converter lockup in all modes. All controls to the transmission are initiated by the driver, including the brake system, which is operated by a foot pedal. The transmission provides a hydrostatic steering system and integral hydraulic brakes.

Section II. CONSTRUCTION AND OPERATION

25-3. General. There are several models of cross-drive transmissions. This discussion will limit itself to the X1100-3B unit; all other models are covered in chapter 24. Figure 25-1 shows an external view of the X1100-3B cross-drive transmission, while figure 25-2 illustrates the main subassemblies in the transmission.

25-4. Torque Converter. The torque converter used in the X1100-3B is a three-element assembly including a pump, stator, and turbine. The pump assembly is the input element and is driven by the engine. The converter turbine is the output element and is splined to the turbine shaft assembly. The stator is the reaction (torque multiplying) element. A lockup clutch is used in the torque converter. It serves to provide a direct drive from the engine to the transmission. Both converter phase and lockup phase are illustrated in figure 25-3. Details of torque converter operation are found in paragraph 21-7.

25-5. Planetary Gearing in Gear Ranges.

a. General. The range planetary pack consists of hydraulically applied clutches and planetary gearing which provide the four forward speeds and two reverse speeds. The range pack consists of five clutches and three planetary gearsets. All forward and reverse ranges are engaged by applying two clutches at a time in various combinations. Range shifts are accomplished by changing the application of a single clutch.

b. Neutral. There are no clutches applied in neutral; therefore, torque produced in the converter is not transmitted beyond the range input gear and forward clutch housing. Figure 25-4 illustrates the power flow in the neutral position.

c. First Range. In the first range, the forward and first clutches are applied. The first clutch application anchors the rear planetary ring gear against rotation. The forward clutch application locks the range input gear and main shaft together to rotate as a unit. The rear sun gear is splined to the main shaft and rotates with it and, in turn, rotates the rear planetary pinions. The pinions are part of the carrier assembly that is splined to the range output gear. With the ring gear held stationary by the applied first clutch and rear sun gear rotating the pinions, the rear planetary carrier must rotate within the ring gear and drive the range output gear. Figure 25-5 illustrates the power flow in first range.

d. Second Range. As the selector is placed in the second range, the forward and second clutches are applied. The second clutch application anchors the carrier of the front planetary assembly against rotation. The forward clutch application locks the range input gear and main shaft together to rotate as a unit. The rear sun gear is splined to both the rotating main shaft and the center ring gear, and all three parts rotate at one input speed. With the carrier of the front planetary assembly anchored against rotation (by second-clutch application), the rotating

491

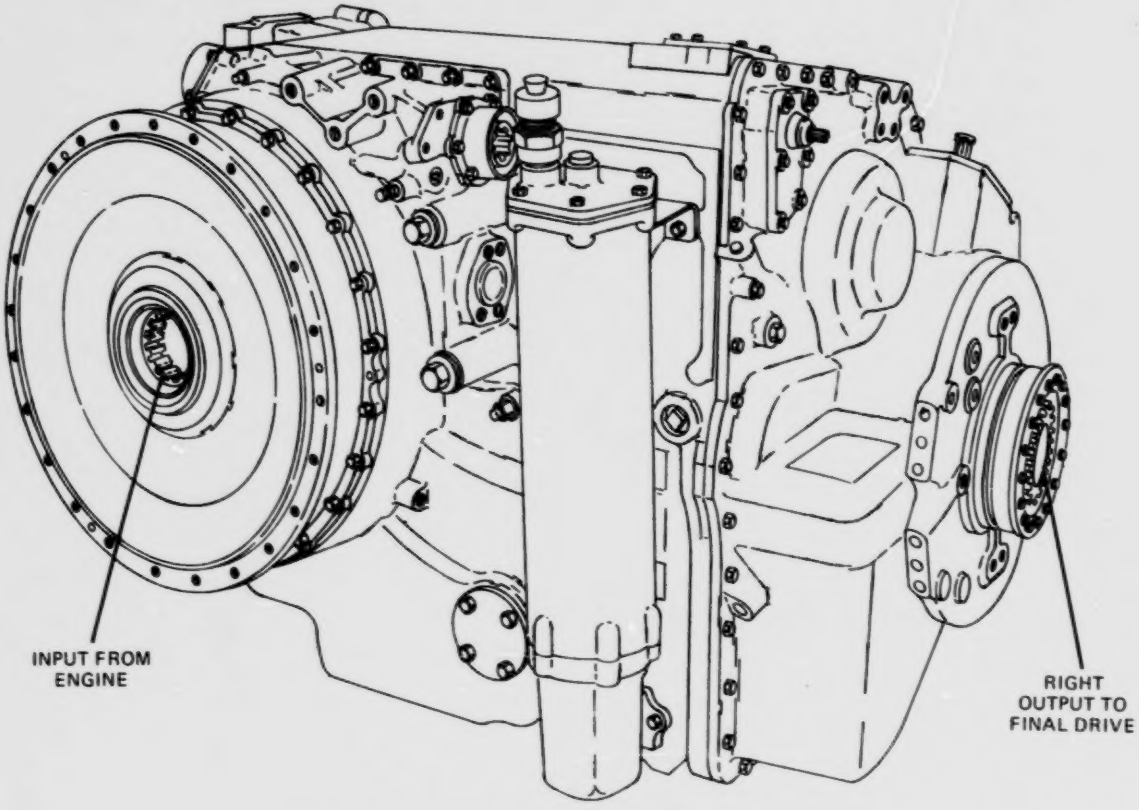


Figure 25-1. X1100 Transmission – External View.

center ring gear rotates the center sun gear via the planetary pinions. This sun gear is splined to the sun gear shaft assembly to which the front sun gear also is splined. The rotating front sun gear rotates the front carrier pinions whose carrier is anchored against rotating by the applied second clutch. In turn, the rotating front carrier pinions rotate the front ring gear, which, along with the center carrier, is splined, via the front ring gear and rear carrier assembly, to the range output gear. Figure 25-6 illustrates the power flow through the X1100 transmission in second range.

e. Third Range. In this configuration the forward and third clutches are applied. The third clutch application anchors the sun gear shaft against rotation, which, in turn, prevents the center sun gear (splined to rear of shaft) from rotating. The forward clutch application locks the range input gear and main shaft together to rotate as a unit. The rear sun gear is splined to both the main shaft and the center ring gear and rotates at range input speed. With the center sun gear stationary and the center ring gear rotating, the ring gear drives the center planetary carrier pinions. This rotates the center planetary carrier at a speed reduction. This carrier (and also the rear planetary carrier) is splined to the front ring gear and rotates with it as a unit. The rear carrier is splined to the range output gear which rotates with the rear carrier at the same speed as the center planetary carrier. Figure 25-7 illustrates the power flow in third range.

f. Fourth Range. In this configuration the forward and fourth clutches are applied. With the clutches applied, the transmission main shaft and the sun gear shaft are locked together and rotate as a unit at range input speed. With the center and rear sun gears rotating at the same speed (locked together), and their carriers splined to the front ring gear, all components rotate at range input speed. The transmission range output gear is splined to the rear carrier and gives a range output ratio of 1.00:1. The fourth range power flow is illustrated in figure 25-8.

TA233743

492

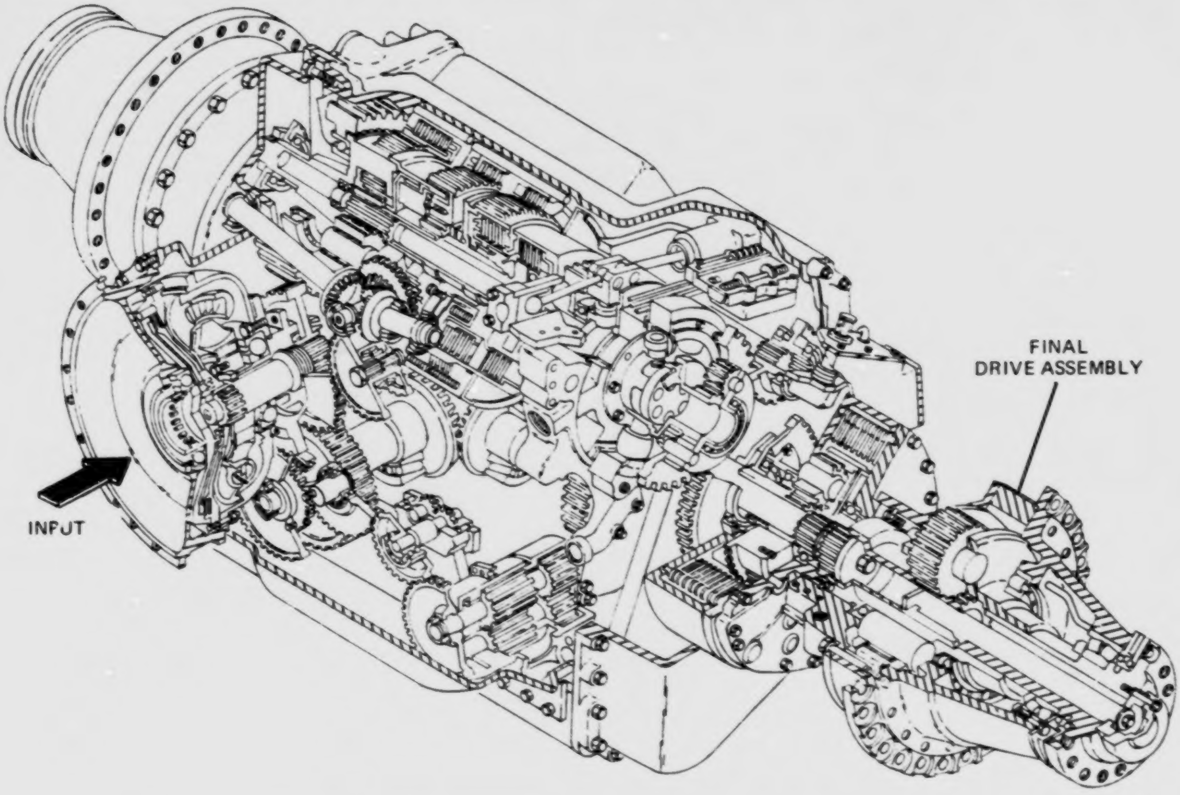

FINAL
DRIVE ASSEMBLY
INPUT

Figure 25-2. X1100 Transmission – Internal View.

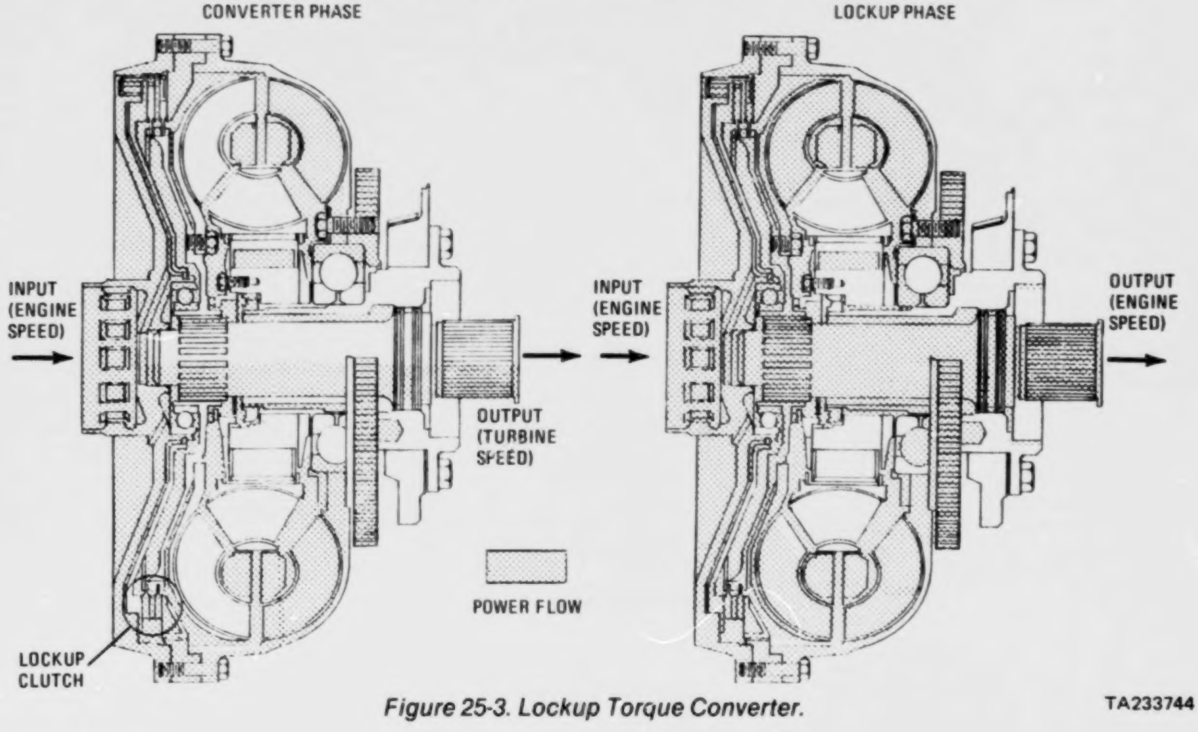
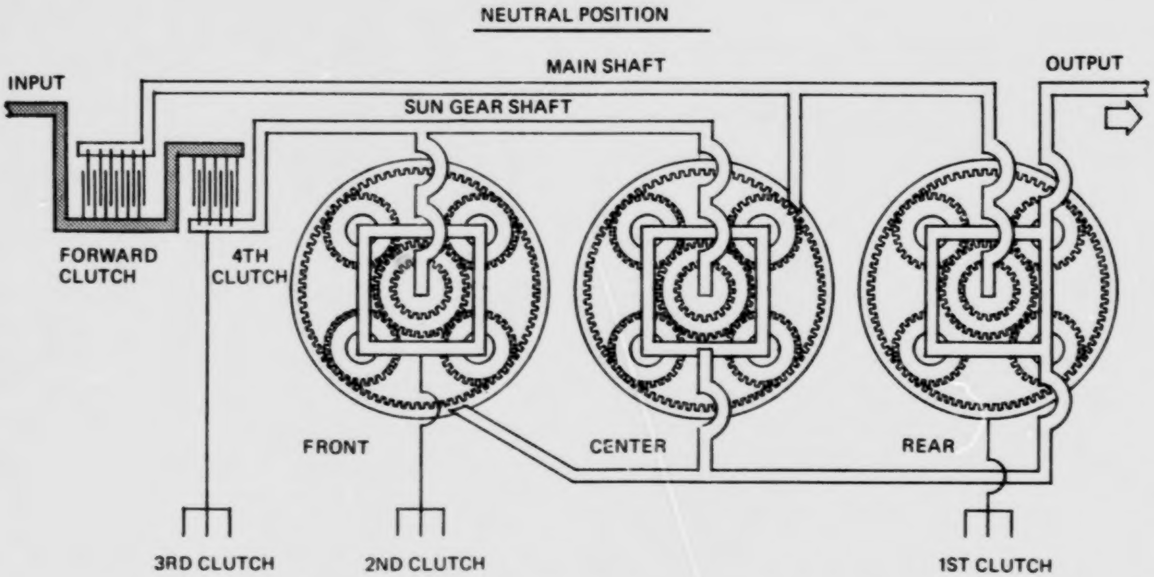

CONVERTER PHASE
LOCKUP PHASE
INPUT
(ENGINE
SPEED)
OUTPUT
(TURBINE
SPEED)
INPUT
(ENGINE
SPEED)
OUTPUT
(ENGINE
SPEED)
POWER FLOW
LOCKUP
CLUTCH

Figure 25-3. Lockup Torque Converter.

TA233744



CLUTCH	ENGAGED	DISENGAGED
FORWARD		X
1ST		X
2ND		X
3RD		X
4TH		X

Figure 25-4. Power Flow through X1100 Transmission in Neutral.

g. Reverse 1 Range. The reverse ranges are the only ranges in which the forward clutch is not engaged. In reverse 1, the fourth clutch is applied and this rotates the sun gear shaft assembly (with the front and center sun gears splined to it) at range input speed. The first clutch also is applied, which anchors the rear ring gear against rotation. The center sun gear rotates the center carrier pinions, which, in turn, rotate the center ring gear in an opposite direction. The center carrier is splined to the front ring gear which is splined to the rear carrier. The reverse direction of rotation of the center ring gear rotates the rear sun gear. This causes the rear planetary pinions to drive the rear carrier in a reverse direction within the stationary ring gear. This compounding action of the center and rear planetary gives rotation with a speed reduction to the rear carrier, which is splined to the range output gear. Figure 25-9 illustrates the X1100 transmission in reverse 1 range.

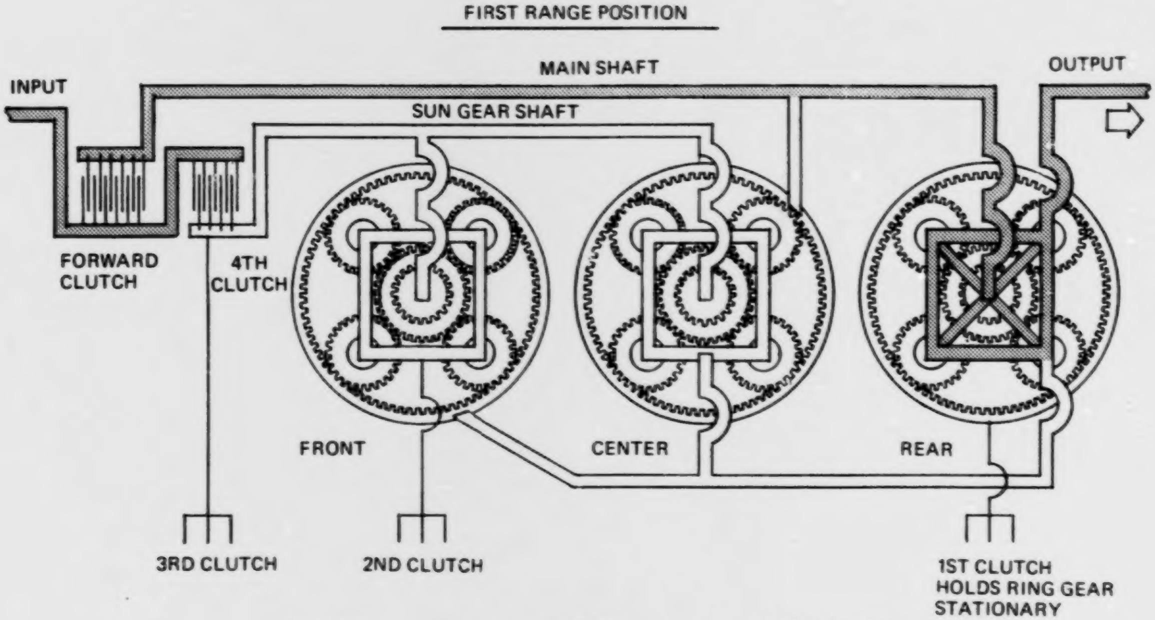
h. Reverse 2 Range. In reverse 2 range, the fourth clutch is applied which rotates the sun gear shaft assembly (with the front and center sun gears splined to it) at range input speed. The second clutch also is applied, which anchors the front carrier assembly against rotation. The rotating front sun gear rotates the front carrier pinions whose carrier is anchored against rotating by the applied second clutch. This causes the front carrier pinions to drive the front ring gear in a reverse rotation. The front ring gear is splined to the rear carrier assembly which drives the range output gear. The power flow in reverse 2 is illustrated in figure 25-10.

25-6. Steering.

a. General. The X1100 steer system consists mainly of a variable-volume hydrostatic pump, a fixed-volume hydrostatic motor, a steer-control valve system, gearing to drive the pump, and gearing by which the motor produces steer action.

The hydrostatic pump is driven continuously while the engine is operating through a gear train

TA233745



CLUTCH	ENGAGED	DISENGAGED
FORWARD	X	
1ST	X	
2ND		X
3RD		X
4TH		X

Figure 25-5. Power Flow through X1100 Transmission in First Range.

connecting the converter turbine to the hydrostatic pump. During straight travel, the hydrostatic pump produces no flow or pressure. When steer is desired, the pump will produce flow from either of two ports, depending upon whether right or left steer is desired. The amount of flow produced depends upon the degree of steer desired.

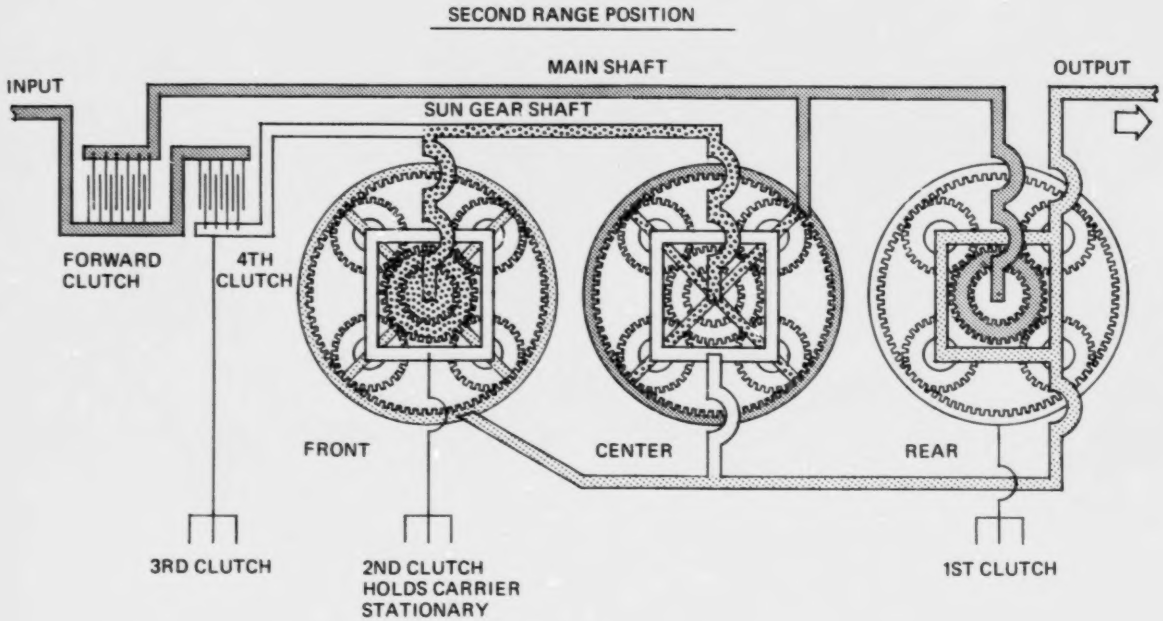
Flow from either port of the pump is directed to the hydrostatic motor. This port becomes the input of the motor. The remaining port is the motor output, and returns flow to the pump input. Thus, the inputs and outputs of the pump and motor are reversed when steering is changed from left to right, or right to left. The direction in which the hydrostatic motor rotates is determined by whether right or left steer is applied.

The mechanical output of the motor is connected by gears to a differential arrangement which drives sun gears of two planetary gearsets in opposite directions. This differential arrangement is stationary during straight travel and the sun gears act as reaction elements in the planetary sets, providing equal rotation to the sun gears in the output planetaries. When steer is applied, the differential sun gears are driven in opposite directions. Thus, one of them adds speed to one output sun gear while the other subtracts speed from the opposite output sun gear. This speeds up one power train output, while slowing down the opposite output an equal amount. The hydrostatic steer unit is illustrated in figure 25-11 and a hydraulic diagram of the system is shown in figure 25-12.

b. Left and Right Steering. When steer is applied, the servo valve is rotated to the extent required to produce the desired steer. This directs pressure to the control piston which controls the pump piston stroke. For steer in one direction, it is one of the control pistons; for steer in the other direction, it is the other piston. The piston opposite the one being pressurized remains exhausted.

TA233746

495



CLUTCH	ENGAGED	DISENGAGED
FORWARD	X	
1ST		X
2ND	X	
3RD		X
4TH		X

Figure 25-6. Power Flow through X1100 Transmission in Second Range.

The pressurized control piston rotates the hanging ring to a position that causes the hydrostatic pump pistons to reciprocate. The length of their stroke corresponds to the degree of steer applied, and the hydraulic output of the hydrostatic pump is directly proportional to the stroke. Oil flow from the moving pistons now is directed to the proper port of the motor. This produces the movement required to drive the sun gears of the planetary gearsets. Figures 25-13 and 25-14 illustrate action during left and right steering.

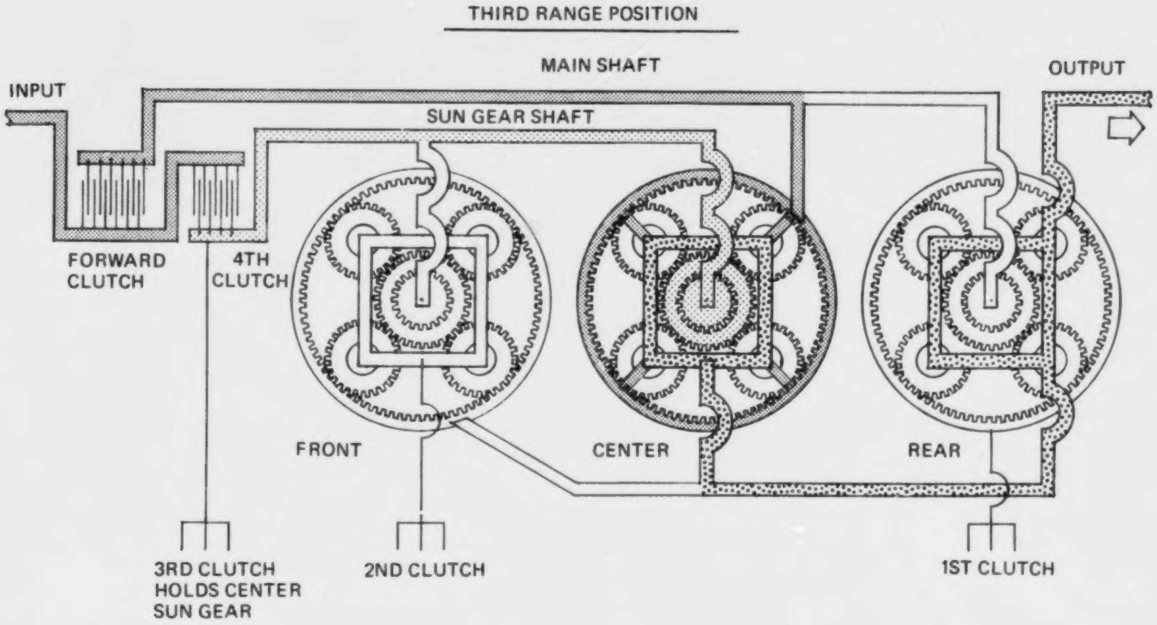
25-7. Components. In addition to the components mentioned above, other elements are used in the steering system. Each is discussed below.

a. Supercharge Check Valves (Fig. 25-12). Two supercharge check valves are provided in the line between the main pressure regulator and the hydrostatic pump. One check valve is open at all times to provide additional oil to the hydrostatic pump circuit as required to replenish oil lost in leakage during overload, or in control functions. The other valve remains closed. The direction of rotation determines when each valve is opened or closed. Oil is supplied through the open valve to the input side of the hydrostatic pump.

b. Control Pumps (Fig. 25-12). The control pumps further pressurize the oil before it is directed to the hydrostatic pump control system. The output of the control pumps is directed to three points: the first point is the control pressure regulator valve; the second is the secondary control pressure regulator; and the third is the rotary servo unit.

c. Servo Sleeve. The servo sleeve is a rotating sleeve valve with ports to direct control pressure to the control pistons. The servo sleeve is centered on the same axis as the hanging ring (mechanism that controls the pump piston stroke) and is

TA233747



CLUTCH	ENGAGED	DISENGAGED
FORWARD	X	
1ST		X
2ND		X
3RD	X	
4TH		X

Figure 25-7. Power Flow through X1100 Transmission in Third Range.

connected to the hanging ring by a pin. The pin transmits the partial rotation of the hanging ring to the servo sleeve.

d. Servo Valve (Fig. 25-12). Centered within the servo sleeve is the manually controlled servo valve which, when rotated, directs control pressure to either of the two control pistons. Clockwise rotation of the servo valve from its normally centered position gives steer in one direction; counterclockwise rotation gives steer in the other direction. The control pistons have no pressure acting upon them when no steer is applied. Their oil lines are open to exhaust through the servo valve.

e. Stroke Limiter Valve (Fig. 25-12). A stroke limiter valve is provided in the control circuit. Under normal condition the valve remains in the position shown. Under conditions that overload the hydrostatic pump (approximately 5000 psi), the excessive output pressure pushes the valve to a position that interrupts the control pressure circuit actuating the control pistons. This action overrides steer control to the extent of reducing steer to the degree possible under overload conditions.

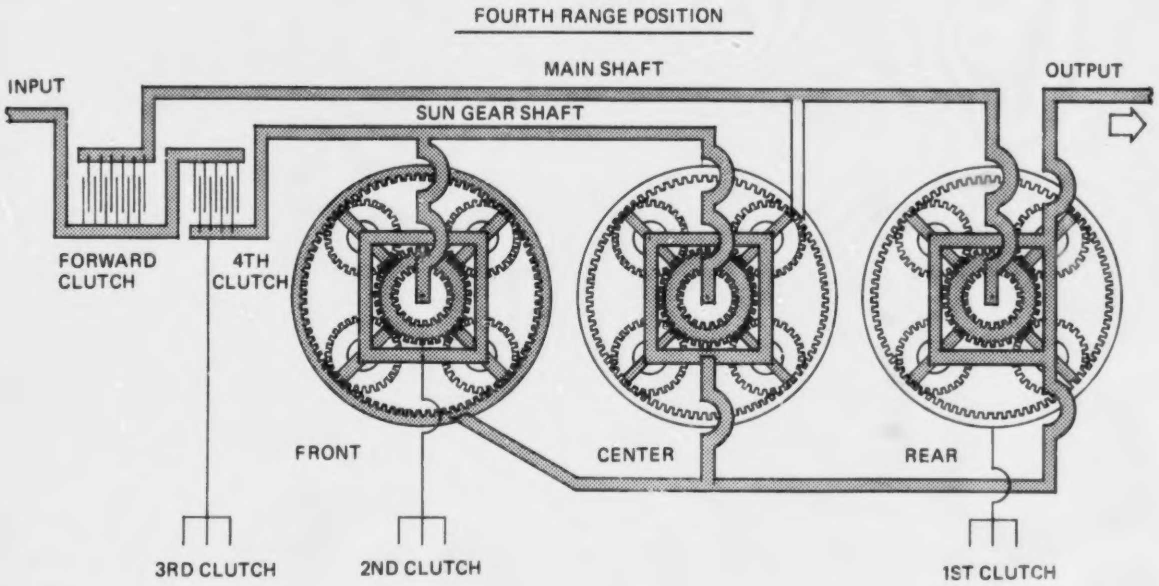
25-8. Final Drive.

a. General. The final drive assembly (fig. 25-15) is a self-contained, heavy-duty planetary gear speed-reduction unit. The input spline is integral with the planetary sun gear. The planetary ring gear is bolted to the final drive housing and, therefore, is stationary. The planetary carrier, with planet pinion gears, is splined to the output shaft. The final drive unit is identical for both left and right transmission outputs. The dry weight of each final drive is approximately 940 lb.

The oil supply is contained in the bottom of the housing and provides both cooling and lubrication for the unit. Lubrication is obtained by the splash

TA233748

1197



CLUTCH	ENGAGED	DISENGAGED
FORWARD	X	
1ST		
2ND		
3RD		
4TH	X	

Figure 25-8. Power Flow through X1100 Transmission in Fourth Range.

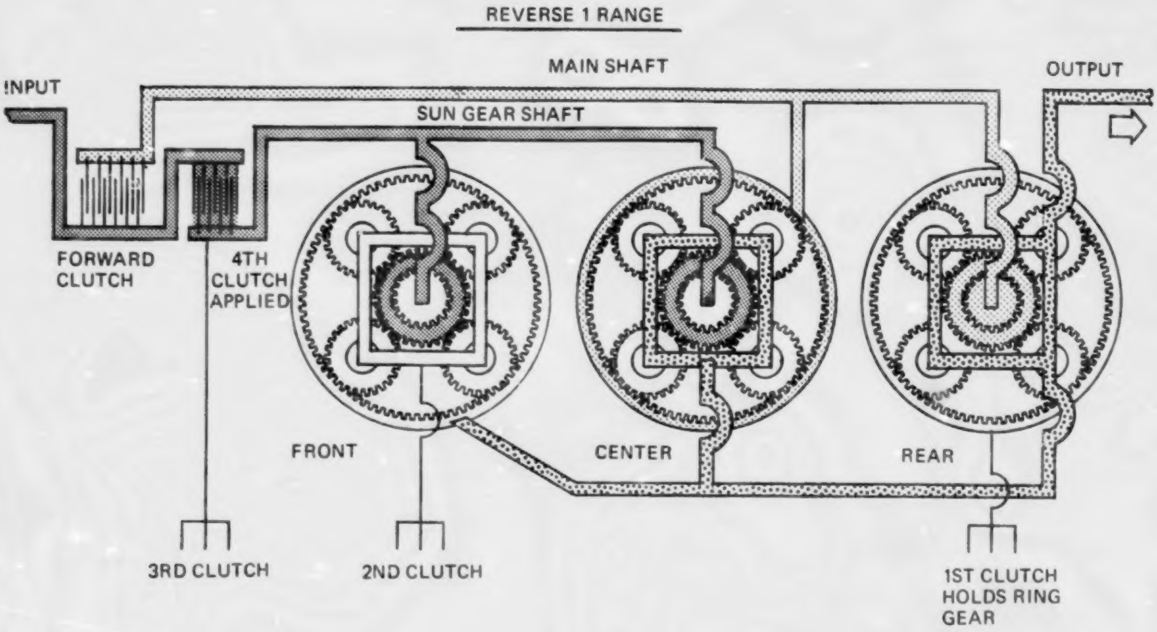
method since the pinion gears are running in oil all the time and carry the oil around the housing with them. The final drive uses the same oils as the transmission.

b. Transmission/Final Drive Interface. The two transmission mounting trunnions fit into mating saddle assemblies of the final drives. The left trunnion of the transmission has a locating ring that fits in a groove in the final drive. This ring positions the transmission in the vehicle and prevents lateral movement. Saddle caps bolt on and secure the transmission trunnions to the final drives. The transmission output shafts are connected to the final drives by the splined sun gears, located in each final drive, that slide into engagement with the drive splines on the transmission output shafts. This configuration also permits external disengagement from the transmission for high speed or extensive towing of the vehicle.

The final drive input spline, integral with the sun gear, receives transmission output torque and transmits it through the planetary carrier to the final drive output shaft. The output shaft carries the torque to the vehicle track sprocket to propel the vehicle. The gear reduction ratio is 4.30:1 and input and output rotation are in the same direction.

TA233749

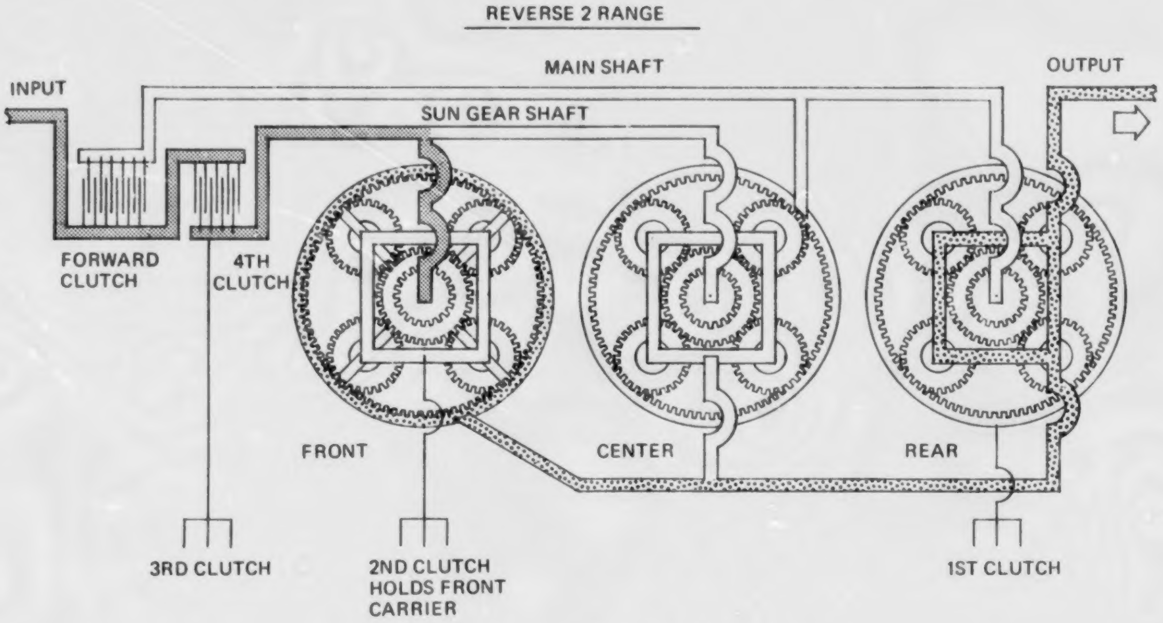
498


REVERSE 1 RANGE
MAIN SHAFT
INPUT
OUTPUT
SUN GEAR SHAFT
FORWARD CLUTCH
4TH CLUTCH APPLIED
FRONT
CENTER
REAR
3RD CLUTCH
2ND CLUTCH
1ST CLUTCH HOLDS RING GEAR

CLUTCH	ENGAGED	DISENGAGED
FORWARD		X
1ST	X	
2ND		X
3RD		X
4TH	X	

Figure 25-9. Power Flow through X1100 Transmission in Reverse 1 Range.

TA233750


REVERSE 2 RANGE
MAIN SHAFT
INPUT
OUTPUT
SUN GEAR SHAFT
FORWARD CLUTCH
4TH CLUTCH
FRONT
CENTER
REAR
3RD CLUTCH
2ND CLUTCH HOLDS FRONT CARRIER
1ST CLUTCH

CLUTCH	ENGAGED	DISENGAGED
FORWARD		X
1ST		X
2ND	X	
3RD		X
4TH	X	

Figure 25-10. Power Flow through X1100 Transmission in Reverse 2 Range.

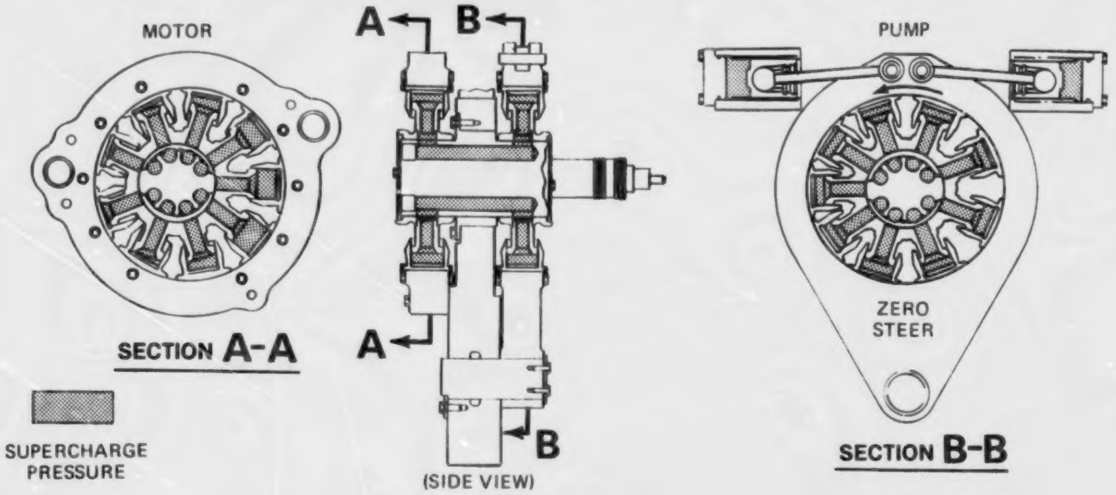

MOTOR
A
B
PUMP
SECTION A-A
A
ZERO STEER
▨ SUPERCHARGE PRESSURE
B
(SIDE VIEW)
SECTION B-B

Figure 25-11. Hydrostatic Steer Unit-Zero Steer.

TA233751

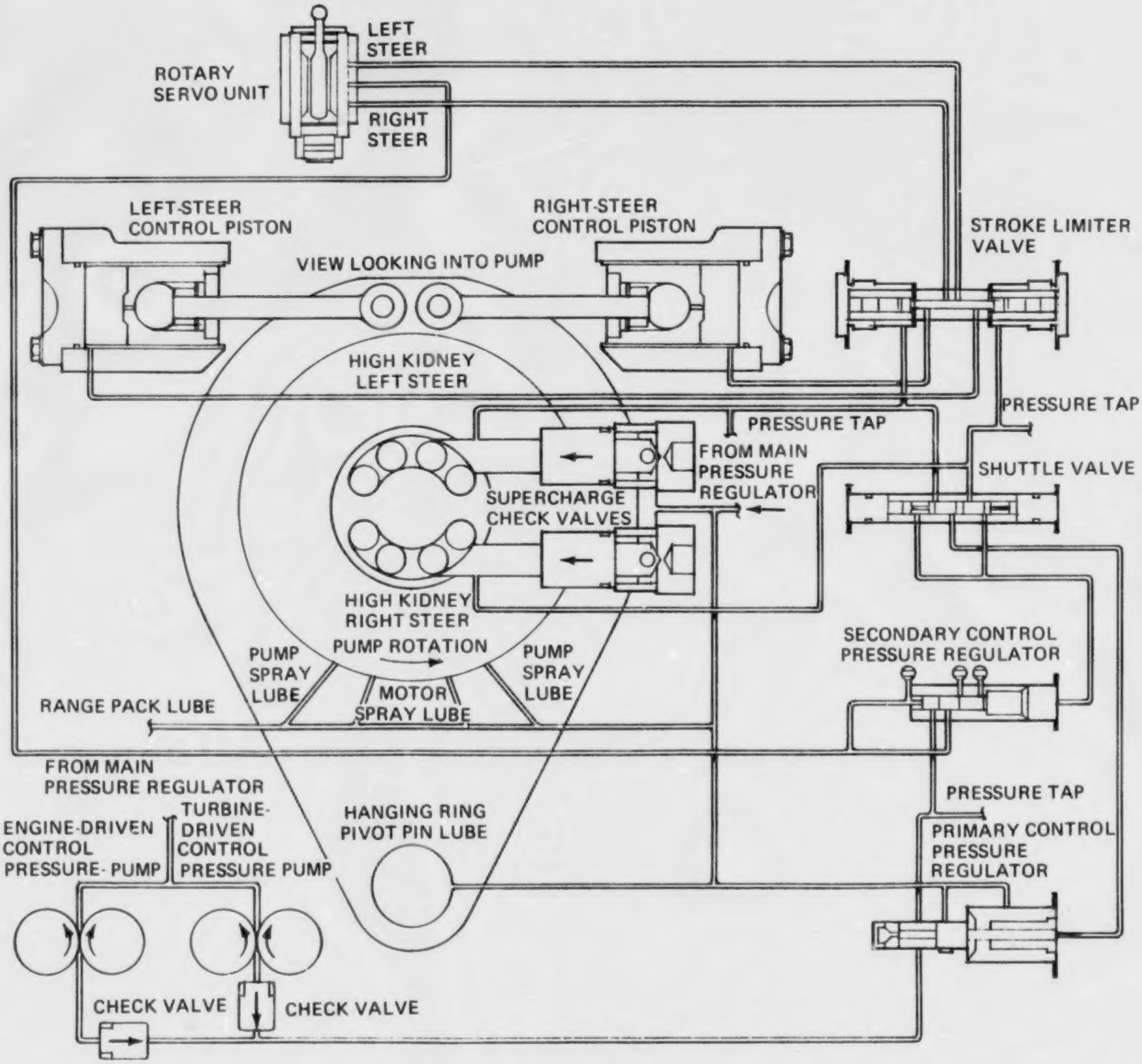

LEFT STEER
ROTARY SERVO UNIT
RIGHT STEER
LEFT-STEER CONTROL PISTON
RIGHT-STEER CONTROL PISTON
STROKE LIMITER VALVE
VIEW LOOKING INTO PUMP
HIGH KIDNEY LEFT STEER
PRESSURE TAP
PRESSURE TAP
FROM MAIN PRESSURE REGULATOR
SHUTTLE VALVE
SUPERCHARGE CHECK VALVES
HIGH KIDNEY RIGHT STEER
PUMP ROTATION
SECONDARY CONTROL PRESSURE REGULATOR
PUMP SPRAY LUBE
PUMP SPRAY LUBE
MOTOR SPRAY LUBE
RANGE PACK LUBE
FROM MAIN PRESSURE REGULATOR
PRESSURE TAP
ENGINE-DRIVEN CONTROL PRESSURE-PUMP
TURBINE-DRIVEN CONTROL PRESSURE PUMP
HANGING RING PIVOT PIN LUBE
PRIMARY CONTROL PRESSURE REGULATOR
CHECK VALVE
CHECK VALVE

Figure 25-12. Hydraulic Diagram for X1100 Transmission-Zero Steer.

TA233752

501

BEST COPY AVAILABLE

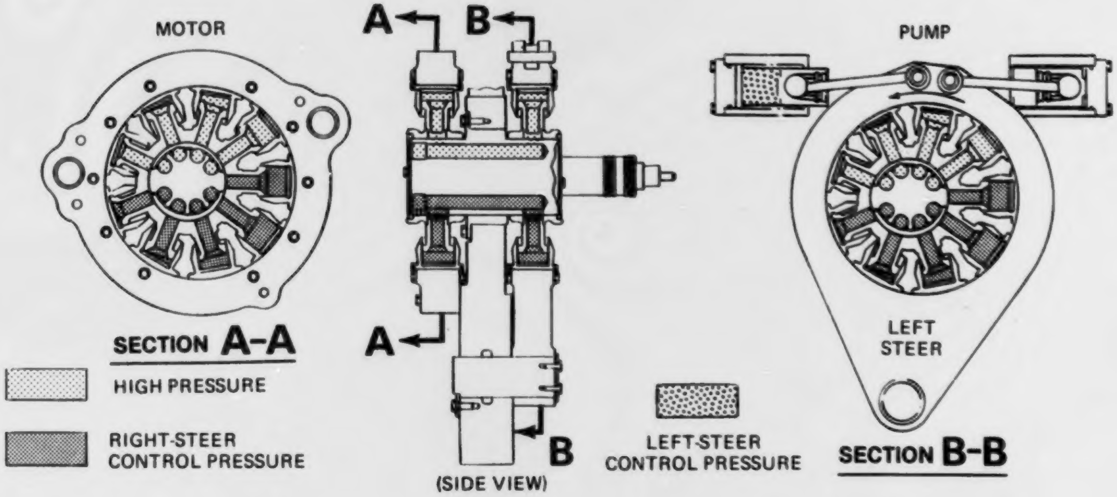

MOTOR
A
B
PUMP
A
LEFT
STEER
SECTION A-A
HIGH PRESSURE
RIGHT-STEER
CONTROL PRESSURE
B
(SIDE VIEW)
LEFT-STEER
CONTROL PRESSURE
SECTION B-B

Figure 25-13. Hydrostatic Steer Unit in Left-Steer Position.

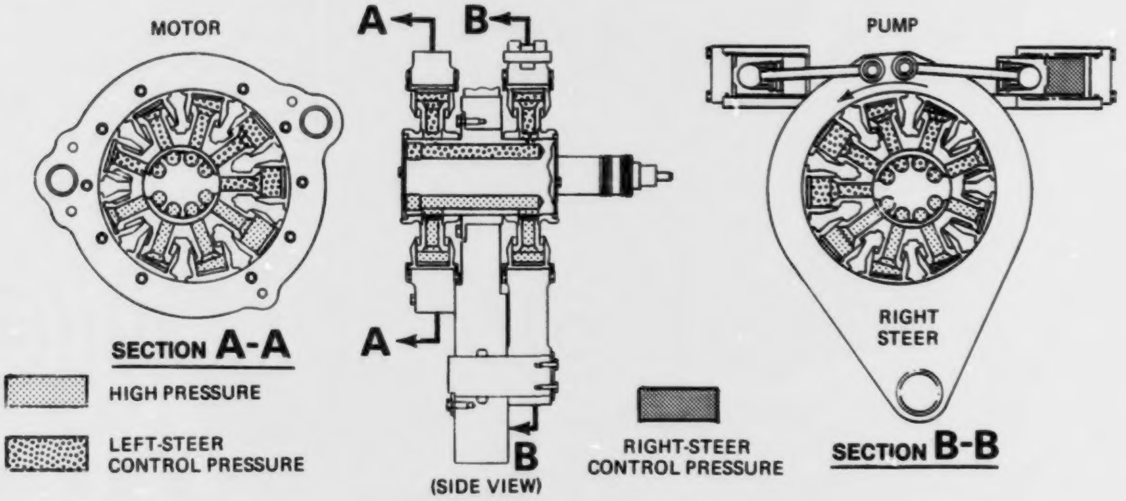

MOTOR
A
B
PUMP
A
RIGHT
STEER
SECTION A-A
HIGH PRESSURE
LEFT-STEER
CONTROL PRESSURE
B
(SIDE VIEW)
RIGHT-STEER
CONTROL PRESSURE
SECTION B-B

Figure 25-14. Hydrostatic Steer Unit in Right-Steer Position.

TA233753

502

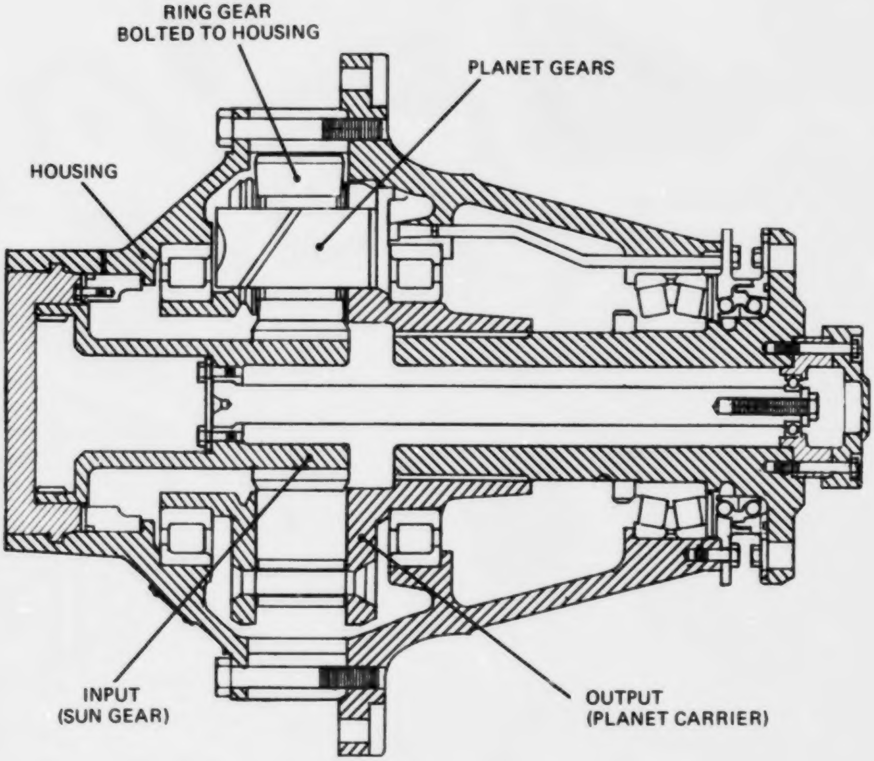

RING GEAR
BOLTED TO HOUSING
PLANET GEARS
HOUSING
INPUT
(SUN GEAR)
OUTPUT
(PLANET CARRIER)

Figure 25-15. Final Drive Assembly.

TA233754

503

CHAPTER 26

AUXILIARY TRANSMISSIONS, SUBTRANSMISSIONS, AND OVERDRIVES

Section I. AUXILIARY TRANSMISSIONS

26-1. Purpose. An auxiliary transmission (fig. 26-1) is used to compound the number of gear ratios that are available from the main transmission. It usually is a separate two-speed transmission that mounts in series between the transmission and the driving axle by utilizing two propeller shafts. By providing two speeds, the auxiliary transmission effectively will double the number of gear ratios available from the main transmission. Vehicles equipped with auxiliary transmissions generally are more versatile than vehicles without them because a low-speed range is available for pulling power and a high-speed (direct-drive) range is available for highway usage.

26-2. Operation (Fig. 26-2). The auxiliary transmission is controlled by a lever in the driver's compartment. The gear ratios usually are selected in the box by a sliding dog clutch. The gear ratios of the auxiliary transmission must be selected while the vehicle is not in motion.

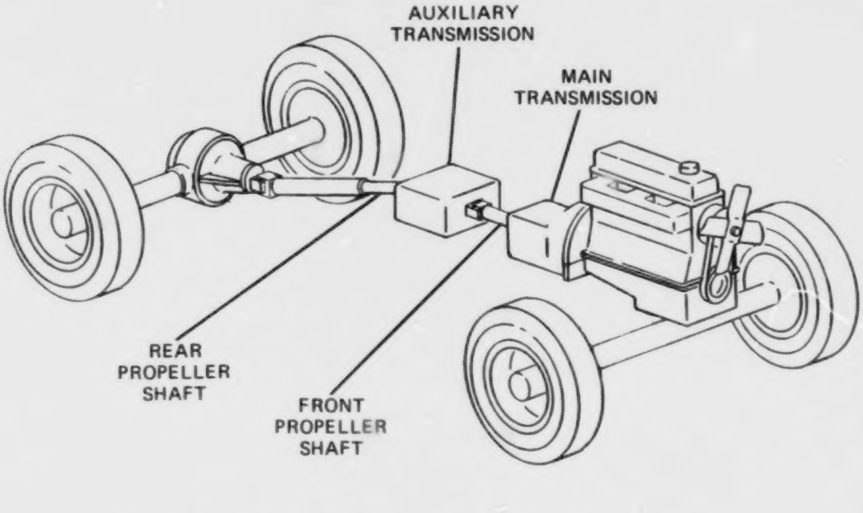


Figure 26-1. Typical Location of Auxiliary Transmission.

TA233755

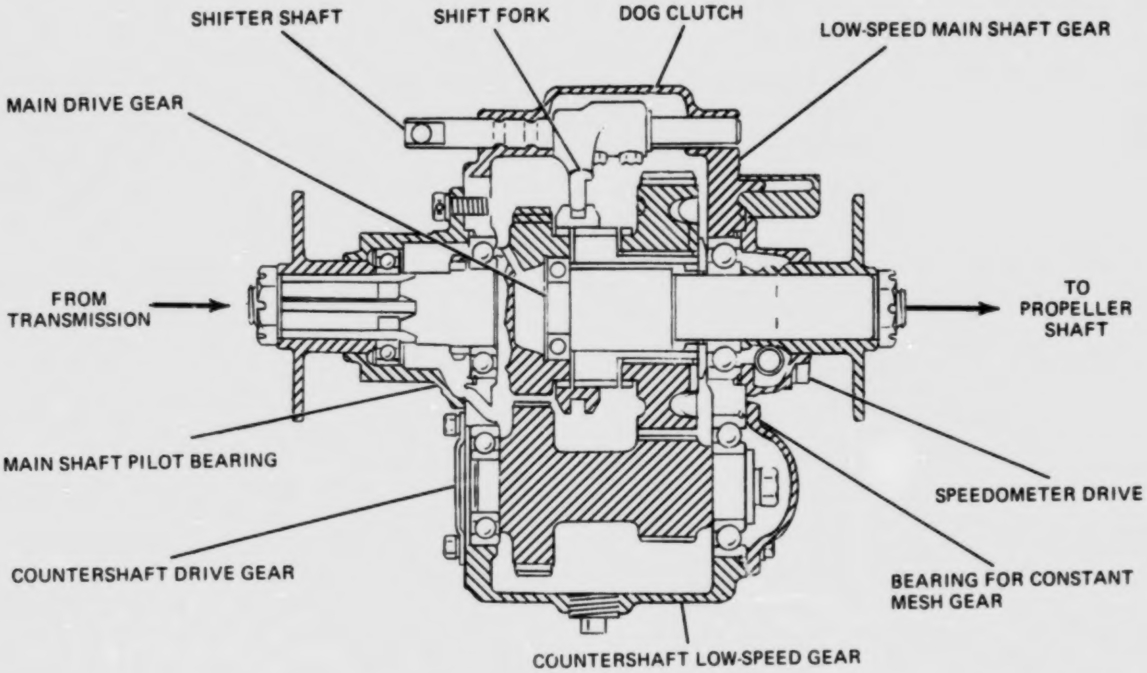

SHIFTER SHAFT
SHIFT FORK
DOG CLUTCH
LOW-SPEED MAIN SHAFT GEAR
MAIN DRIVE GEAR
FROM TRANSMISSION
TO PROPELLER SHAFT
MAIN SHAFT PILOT BEARING
SPEEDOMETER DRIVE
COUNTERSHAFT DRIVE GEAR
BEARING FOR CONSTANT MESH GEAR
COUNTERSHAFT LOW-SPEED GEAR

Figure 26-2. Auxiliary Transmission – Sectional View.

Section II. SUBTRANSMISSIONS

26-3. Purpose. A subtransmission (fig. 26-3) serves the same purpose as the auxiliary transmission (para 26-1). The subtransmission, however, is attached directly to the rear of the main transmission.

26-4. Configuration.

a. Manual. The manual subtransmission operates much the same as the auxiliary transmission, using a control lever in the driver's

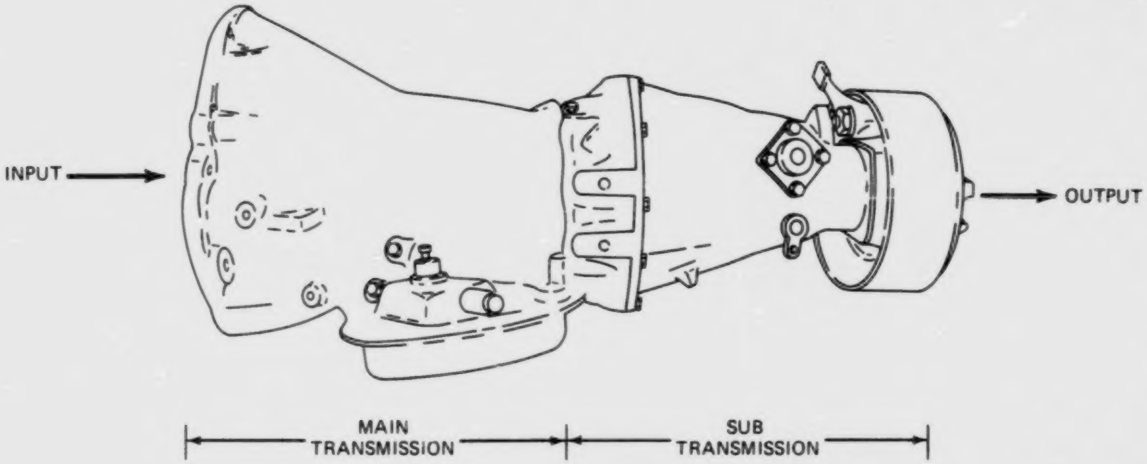

INPUT
OUTPUT
MAIN TRANSMISSION
SUB TRANSMISSION

Figure 26-3. Automatic Subtransmission.

TA233756

compartment. The manual subtransmission is used in conjunction with a manual or an automatic transmission.

b. Automatic. The automatic subtransmission is used by some manufacturers, not as an auxiliary transmission, but as a unit that becomes an integral part of the main transmission. In this configuration, a basic light-vehicle type automatic transmission design is integrated with a subtransmission. The resulting transmission provides four forward gear ratios and sufficient strength for heavy-duty use. In this case, the subtransmission uses a planetary gearset with hydraulically actuated holding elements whose operating principles are much the same as the drive train of an automatic transmission (para 23-5). The shifting of the subtransmission is integrated into the control system of the main transmission and shifting is programmed so that both transmissions function as one.

Section III. OVERDRIVES

26-5. Purpose. A transmission overdrive (fig. 26-4) provides a gear ratio less than 1:1. It reduces engine wear by requiring less revolutions of the engine for a given mileage than required if direct drive is used, and reduces gasoline consumption by providing a more suitable gear ratio for high speeds on level roads. When in operation, the overdrive reduces the engine rear-axle gear ratio by approximately 30 percent. A freewheeling device usually is incorporated in the overdrive, which also helps to save gasoline. The overdrive usually is a separate unit bolted to the rear of the transmission case. In some transmissions, an overdrive is obtained by the gear ratios provided in the transmission.

26-6. Configurations. The overdrive unit sometimes is installed in the vehicle as an integral part of the transmission, much like a subtransmission (para 26-4). In other applications, the overdrive unit is located between the transmission and the driving axle, in series with the drive shaft. The configuration is similar to an auxiliary transmission (para 26-1).

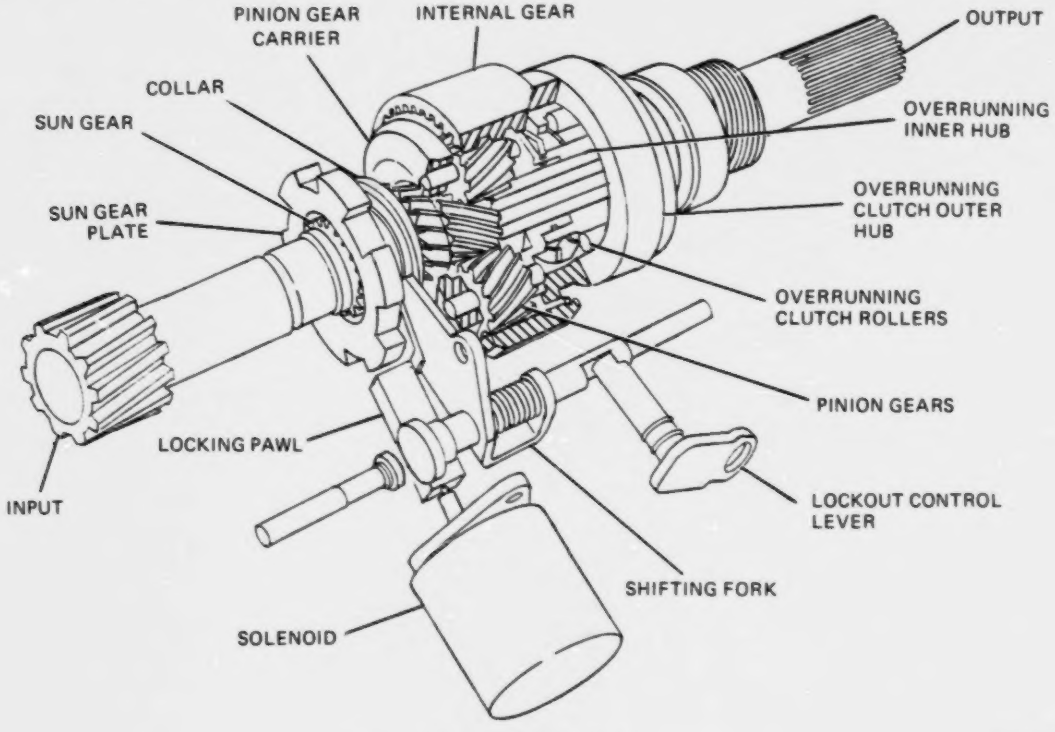

PINION GEAR CARRIER
INTERNAL GEAR
OUTPUT
COLLAR
SUN GEAR
OVERRUNNING INNER HUB
SUN GEAR PLATE
OVERRUNNING CLUTCH OUTER HUB
OVERRUNNING CLUTCH ROLLERS
PINION GEARS
LOCKING PAWL
INPUT
LOCKOUT CONTROL LEVER
SHIFTING FORK
SOLENOID

Figure 26-4. Overdrive Unit.

TA233757

506

26-7. Unit Construction (Fig. 26-5). The basic overdrive unit is a planetary gear-overrunning clutch combination. This combination is necessary in an overdrive unit because the unit must be able to shift while the vehicle is moving. This contrasts with the sliding gears or dog clutches that are used in auxiliary and subtransmissions that can be operated only while the vehicle is not moving. The two factors that control the overdrive modes of operation are:

a. The sun gear is locked to or released from the pinion gear cage. This is accomplished by a mechanical linkage from the operator's controls that, through a fork and collar, slide the sun gear in or out of mesh with the gear teeth cut into the pinion carrier.

b. The sun gear is held stationary or allowed to rotate freely. This is accomplished by a solenoid-operated pawl that engages a notched plate that is attached to the sun gear. The solenoid is actuated by an electrical control system (para 26-9). Various combinations of the above factors are used to produce the three modes of operation that will be discussed in the next paragraph.

26-8. Operation. The overdrive unit is semi-automatic in operation. When a minimum speed is reached (usually about 25 miles per hour) the overdrive unit automatically will engage if the driver releases the accelerator pedal momentarily. A control lever also is provided that locks out the overdrive unit mechanically. The modes of operation are:

a. Locked Out (Fig. 26-5). The locked-out mode of the overdrive is used whenever the use of overdrive is not desired. The locked-out mode is selected by the operator through the movement of an instrument panel mounted lever. The movement of this lever slides the sun gear into mesh with the internal gear teeth in the pinion carrier, resulting in the two members locking together. The locking of the sun gear to the pinion carrier

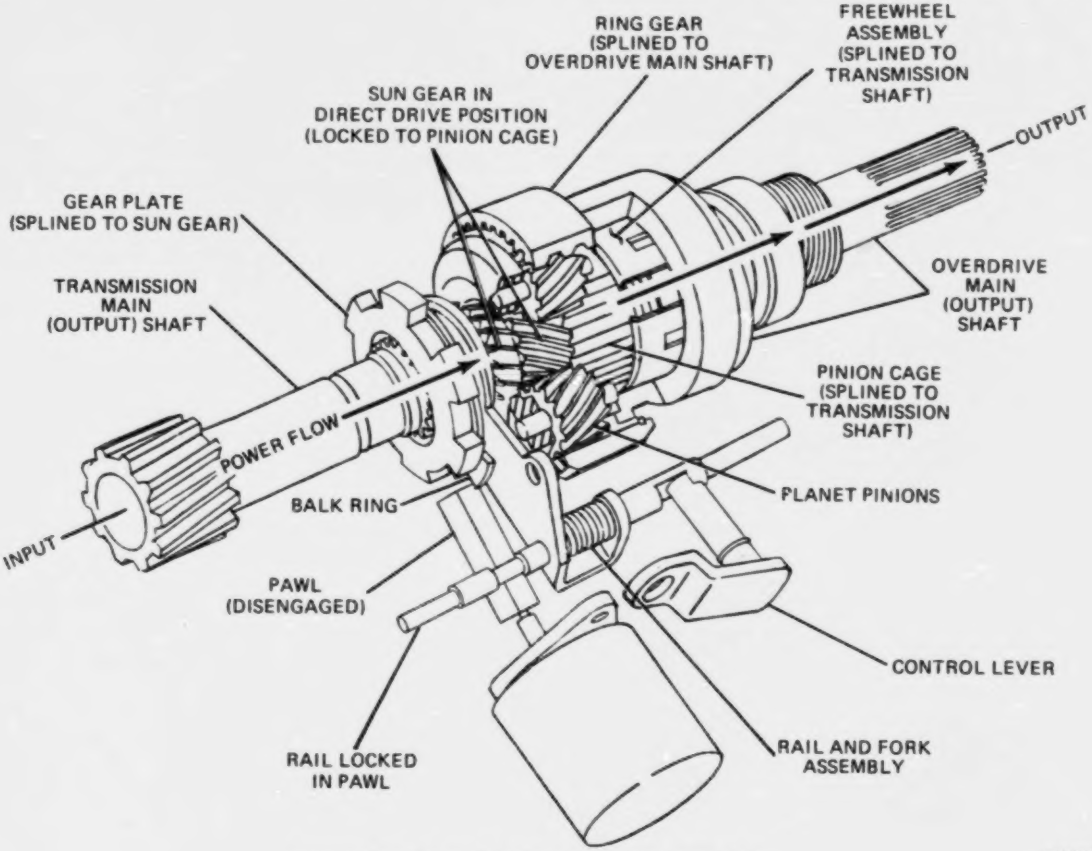

RING GEAR (SPLINED TO OVERDRIVE MAIN SHAFT)
FREEWHEEL ASSEMBLY (SPLINED TO TRANSMISSION SHAFT)
SUN GEAR IN DIRECT DRIVE POSITION (LOCKED TO PINION CAGE)
OUTPUT
GEAR PLATE (SPLINED TO SUN GEAR)
TRANSMISSION MAIN (OUTPUT) SHAFT
OVERDRIVE MAIN (OUTPUT) SHAFT
PINION CAGE (SPLINED TO TRANSMISSION SHAFT)
POWER FLOW
PLANET PINIONS
BALK RING
INPUT
PAWL (DISENGAGED)
CONTROL LEVER
RAIL LOCKED IN PAWL
RAIL AND FORK ASSEMBLY

Figure 26-5. Overdrive in Locked-Out Position.

TA233758

results in the entire planetary gearset rotating as a solid unit.

b. Overdrive (Fig. 26-6). When the operator desires overdrive, the control lever is moved to the overdrive position. This lever movement slides the sun gear out of mesh with the pinion carrier, allowing the planetary gearset to operate. The control system of the overdrive unit will semiautomatically select between the two following modes of operation:

(1) At speeds below approximately 30 mph, the solenoid pawl is disengaged. This combination results in all planetary gearset members being free to rotate. The result will be direct drive through the roller clutch when engine torque is applied. When the accelerator is released, the roller clutch will retract and the vehicle will freewheel.

(2) At speeds above approximately 30 mph (48 km/h), the solenoid is energized and the pawl tries to engage the sun gear plate. The pawl will be blocked by the bulk ring, however, until the engine power flow is interrupted (the operator momentarily releases the accelerator). As the accelerator is released, the sun gear, which is being driven by the pinions, slows down and reverses direction as the overdrive unit begins to freewheel. This reversal of the sun gear causes it to pull back the bulk ring, allowing the pawl to engage the sun gear plate, locking the sun gear. The locking of the sun gear results in the planetary gearset causing the overdrive effect.

26-9. Overdrive Control System.

a. General (Fig. 26-7). The overdrive unit is semiautomatically operated by an electrical control system that is influenced by vehicle speed, throttle position, and the position of the lockout control lever. The following components make up this system:

(1) *Solenoid.* The solenoid, when energized, operates the sun gear locking pawl. Inside the solenoid are two electromagnetic coils: the pull-in and the hold-in coils. The pull-in coil initially actuates the sun gear locking pawl. To do this, the pull-in coil must be very powerful and, therefore, will use a lot of electic current. Because of this, the pull-in contacts are situated to deenergize the pull-in coil when the solenoid is actuated fully. The hold-in coil, which is somewhat lighter, then is utilized to hold the solenoid in the fully actuated position for the duration of overdrive operation.

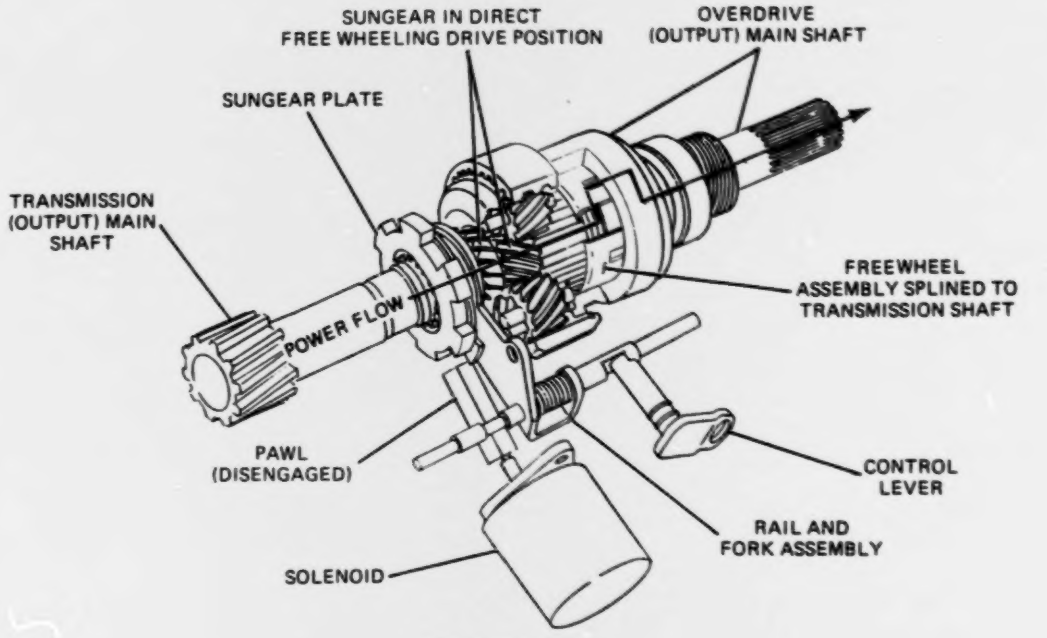
(2) *Solenoid Relay.* The solenoid relay provides power to the solenoid whenever a signal current is applied to it from the signal circuit.

(3) *Governor.* The governor is a centrifugal-type switch that completes the single circuit to the solenoid relay whenever the vehicle reaches approximately 30 mph (48 km/h).

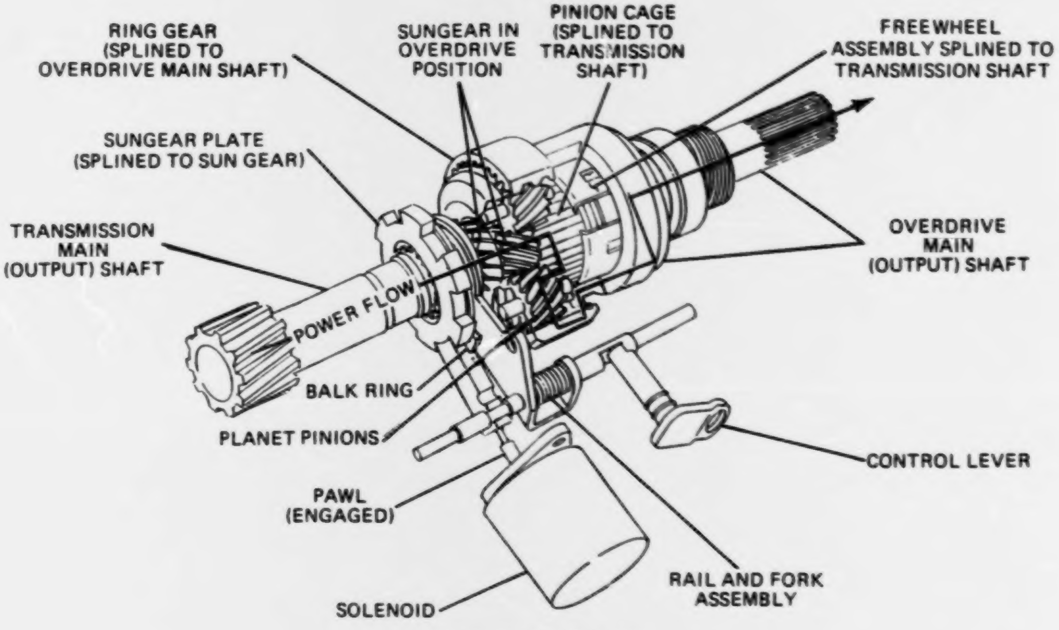
(4) *Rail Switch.* The rail switch interrupts the signal circuit whenever the overdrive unit is locked out, preventing engagement.

(5) *Throttle Switch.* The throttle switch interrupts the signal circuit whenever the accelerator is pressed to the floor, allowing the operator extra power. The throttle switch, in conjunction with the ground-out contacts, also will disable the engine temporarily. This interruption of engine power is necessary to allow the locking pawl to disengage from the sun gear wheel. The process of disengaging the overdrive unit by the action of the throttle switch takes only a fraction of a second.

b. Reverse Lockout. The linkage of the overdrive lockout mechanism is integrated with the transmission so that the lockout is engaged whenever the transmission is shifted to reverse. This arrangement is necessary because the roller clutch will not drive the vehicle in reverse.


SUNGEAR IN DIRECT
FREE WHEELING DRIVE POSITION
OVERDRIVE
(OUTPUT) MAIN SHAFT
SUNGEAR PLATE
TRANSMISSION
(OUTPUT) MAIN
SHAFT
FREEWHEEL
ASSEMBLY SPLINED TO
TRANSMISSION SHAFT
POWER FLOW
PAWL
(DISENGAGED)
CONTROL
LEVER
RAIL AND
FORK ASSEMBLY
SOLENOID

FREEWHEELING


RING GEAR
(SPLINED TO
OVERDRIVE MAIN SHAFT)
SUNGEAR IN
OVERDRIVE
POSITION
PINION CAGE
(SPLINED TO
TRANSMISSION
SHAFT)
FREEWHEEL
ASSEMBLY SPLINED TO
TRANSMISSION SHAFT
SUNGEAR PLATE
(SPLINED TO SUN GEAR)
TRANSMISSION
MAIN
(OUTPUT) SHAFT
OVERDRIVE
MAIN
(OUTPUT) SHAFT
POWER FLOW
BALK RING
PLANET PINIONS
CONTROL LEVER
PAWL
(ENGAGED)
RAIL AND FORK
ASSEMBLY
SOLENOID

OVERDRIVE ENGAGED

Figure 26-6. Overdrive in Engaged Position.

TA233759

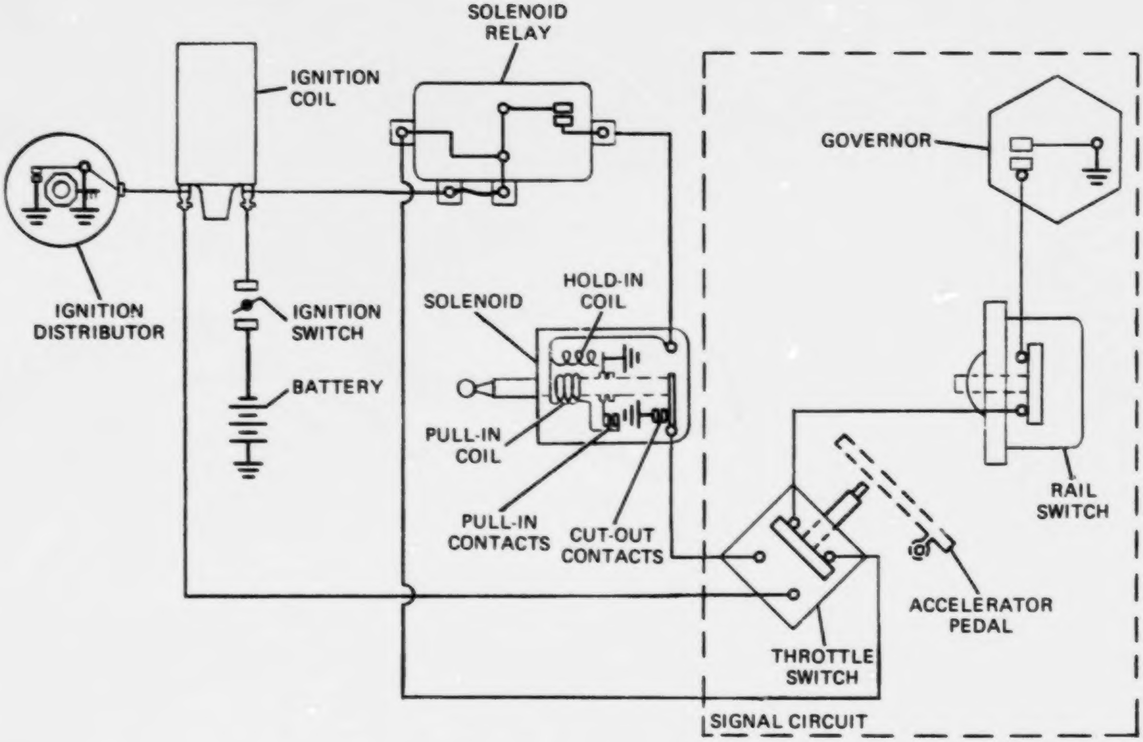

SOLENOID RELAY
IGNITION COIL
GOVERNOR
IGNITION DISTRIBUTOR
IGNITION SWITCH
SOLENOID
HOLD-IN COIL
BATTERY
PULL-IN COIL
PULL-IN CONTACTS
CUT-OUT CONTACTS
RAIL SWITCH
ACCELERATOR PEDAL
THROTTLE SWITCH
SIGNAL CIRCUIT

Figure 26-7. Typical Overdrive Control Circuit.

TA233760

CHAPTER 27

TRANSFER ASSEMBLIES

Section I. PURPOSE

27-1. Divided Engine Torque (Fig. 27-1). Transfer assemblies are used in off-road vehicles to divide engine torque between the front and rear driving axles. The transfer case also allows the front driving axle to be disengaged, which is necessary to prevent undue driveline-component wear during highway use. Another purpose of the transfer case is to move the propeller shaft for the front driving axle off to the side so that it can clear the engine. This arrangement is necessary to allow adequate ground clearance and to allow the body of the vehicle to remain at a practical height from the ground.

27-2. High- and Low-Gear Range. The transfer assembly also provides a high and low final drive gear range in the same manner as an auxiliary transmission. In most cases the shifting of the gear ranges is accomplished through a sliding dog clutch and shifting must be done while the vehicle is not moving.

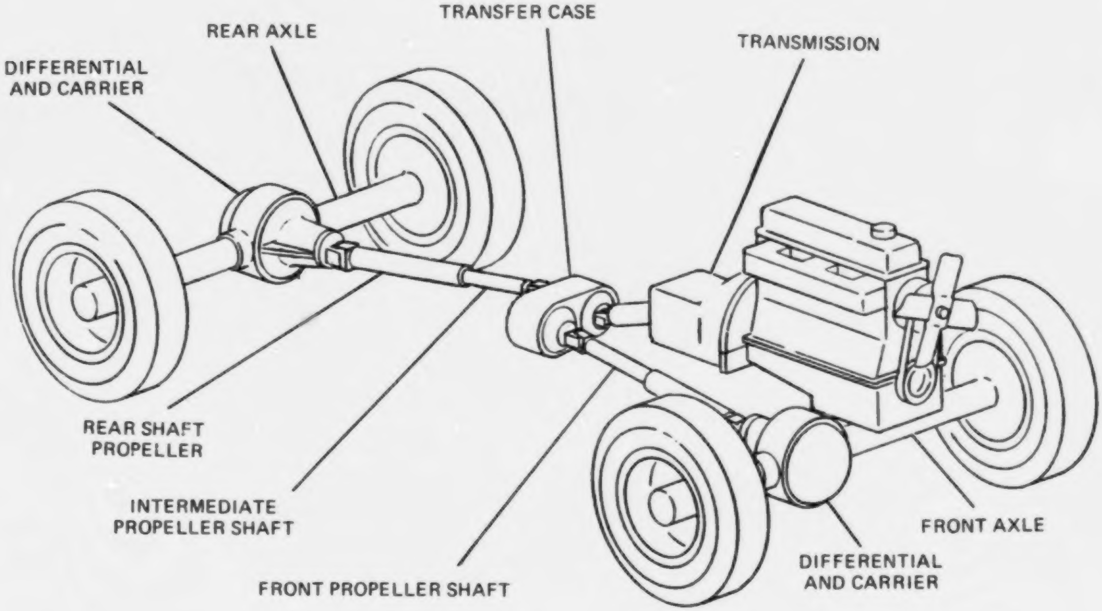

TRANSFER CASE
REAR AXLE
TRANSMISSION
DIFFERENTIAL AND CARRIER
REAR SHAFT PROPELLER
INTERMEDIATE PROPELLER SHAFT
FRONT PROPELLER SHAFT
FRONT AXLE
DIFFERENTIAL AND CARRIER

Figure 27-1. Typical Driveline Arrangement with Transfer Assembly.

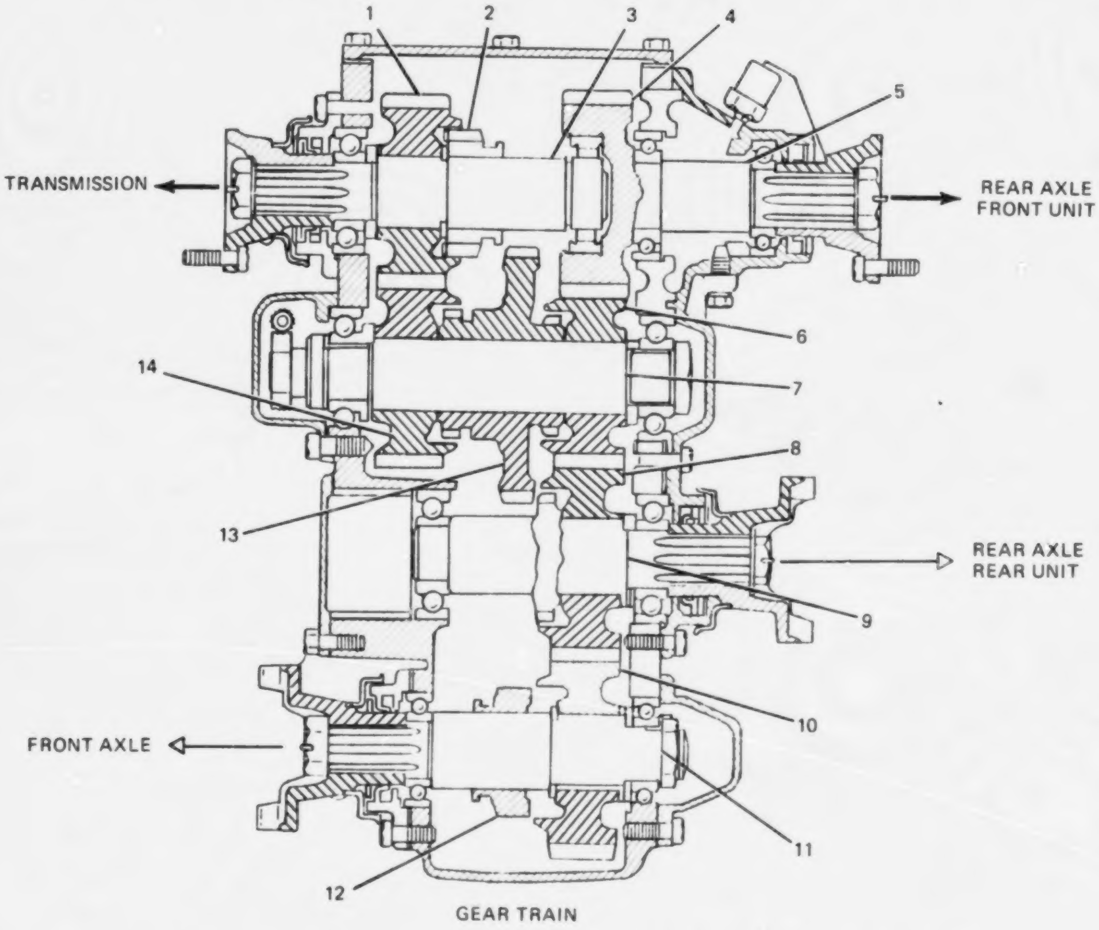
TA233761

Section II. CONVENTIONAL TRANSFER ASSEMBLIES

27-3. General (Fig. 27-2 and 27-3). The conventional transfer case provides full-time torque to the rear axle. Torque transmittal to the front axle is selected by the operator through linkage to a floor-mounted lever. Torque transmittal within the transfer case usually is through gears. Some light-duty applications utilize a chain within the case to transmit torque to the front driving axle. Transfer cases that are used in some 6 x 6 vehicles have a separate provision for each driving axle and a provision for the front driving axle.

27-4. Typical Operation (Fig. 27-4).

a. High Range. When driving both the front and rear axles in the high range (1:1), the external teeth of the sliding gear (splined to the



1. MAINSHAFT CONSTANT MESH GEAR
2. MAINSHAFT SLIDING GEAR
3. MAINSHAFT
4. REAR AXLE (REAR UNIT) DRIVE GEAR
5. REAR AXLE (REAR UNIT) DRIVE GEAR ASSEMBLY
6. IDLER SHAFT CONSTANT MESH GEAR
7. IDLER SHAFT
8. DRIVE SHAFT CONSTANT MESH GEAR
9. REAR AXLE (FRONT UNIT) DRIVE SHAFT
10. DRIVE SHAFT CONSTANT MESH GEAR
11. FRONT AXLE DRIVE SHAFT
12. DRIVE SHAFT SLIDING GEAR
13. IDLER SHAFT LOW SPEED GEAR
14. IDLER SHAFT CONSTANT MESH GEAR

Figure 27-2. Typical Conventional Transfer Assembly for 6 x 6 Vehicles. TA233762

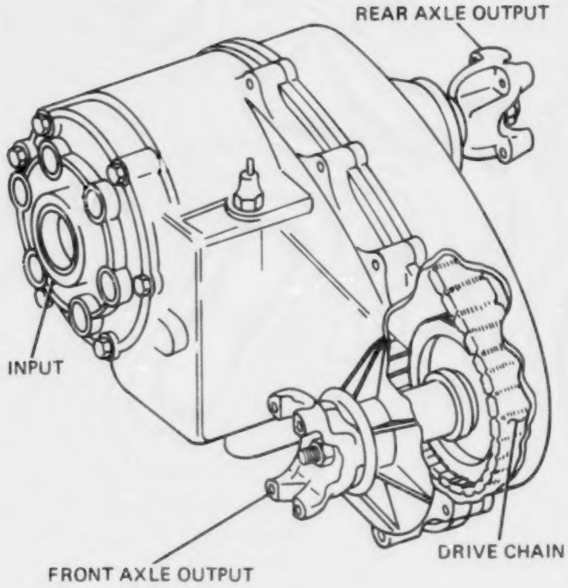
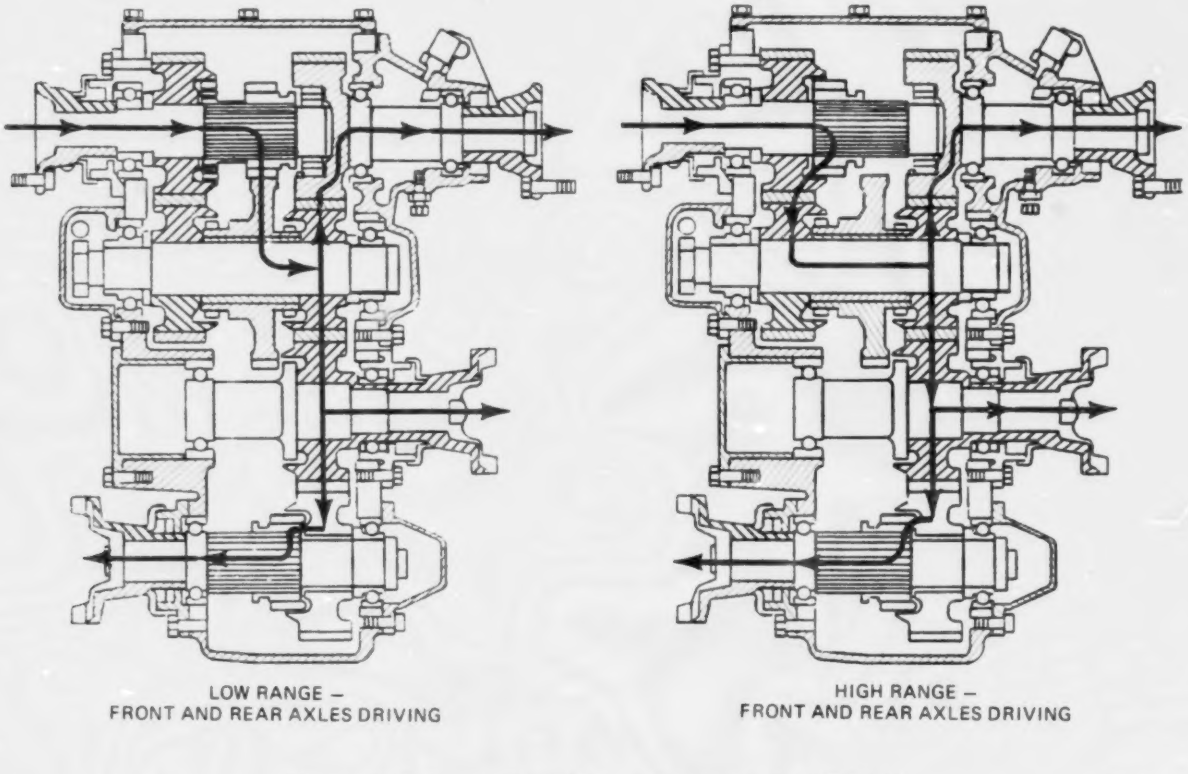


Figure 27-3. Typical Conventional Transfer Assembly using Chain Drive for Front Axle.

transmission main shaft) are in mesh with the internal teeth of the constant mesh gear mounted on this shaft. Likewise, the external teeth of the front-axle sliding gear are in mesh with internal teeth on the constant-mesh gear or the sliding clutches are engaged. Disengagement of the drive to the front axle is accomplished by shifting the sliding gear on the front-axle main shaft out of mesh with the constant-mesh gear, permitting the latter to roll free on the shaft, or sliding the clutches out of mesh.

b. Low Range. When using the low range in the transfer assembly, the sliding gear on the transmission main shaft is disengaged from the constant-mesh gear and engaged with the idler gear on the idler shaft. This reduces the speed by having the sliding gear mesh with the larger idler gear. The shifting linkage on some vehicles is arranged so that shifting into the low range is possible only when the drive to the front axle is engaged. This prevents the driver from applying maximum torque to the rear drive only, which might cause damage.

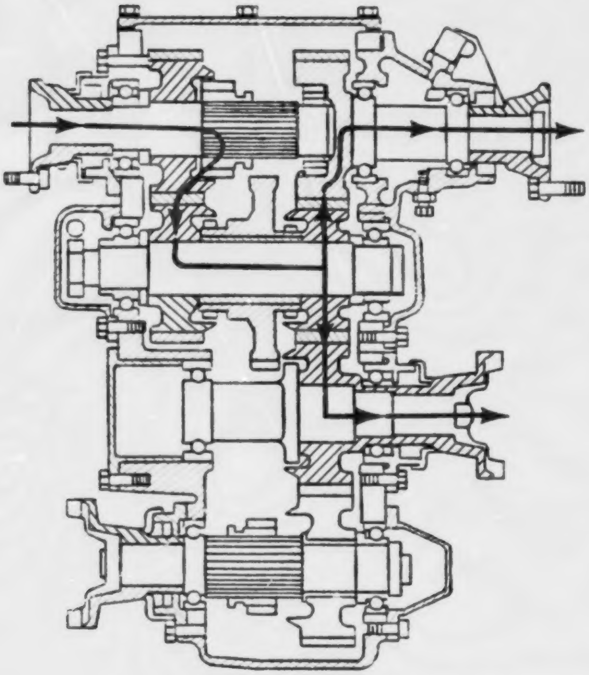


LOW RANGE –
FRONT AND REAR AXLES DRIVING

HIGH RANGE –
FRONT AND REAR AXLES DRIVING

Figure 27-4. Power Flow in Transfer Assembly. (Part A)

TA233763



HIGH RANGE –
REAR AXLES ONLY DRIVING

Figure 27-4. Power Flow in Transfer Assembly. (Part B)

Section III. DIFFERENTIAL-TYPE TRANSFER ASSEMBLIES

27-5. General (Fig. 27-5). The differential-type transfer assembly provides full-time four-wheel drive by the incorporation of differential gears between the front and rear driving axles. The differential action between the front and rear driving axles allows four-wheel drive operation at all times, without the component wear problems that are associated with conventional transfer assemblies. For off-road use, a sliding clutch is provided to lock out the differential unit, providing positive four-wheel drive. This is necessary because the differential will transfer all torque to either drive axle if it loses traction, disabling the vehicle. The differential lockout is engaged by a lever in the passenger compartment.

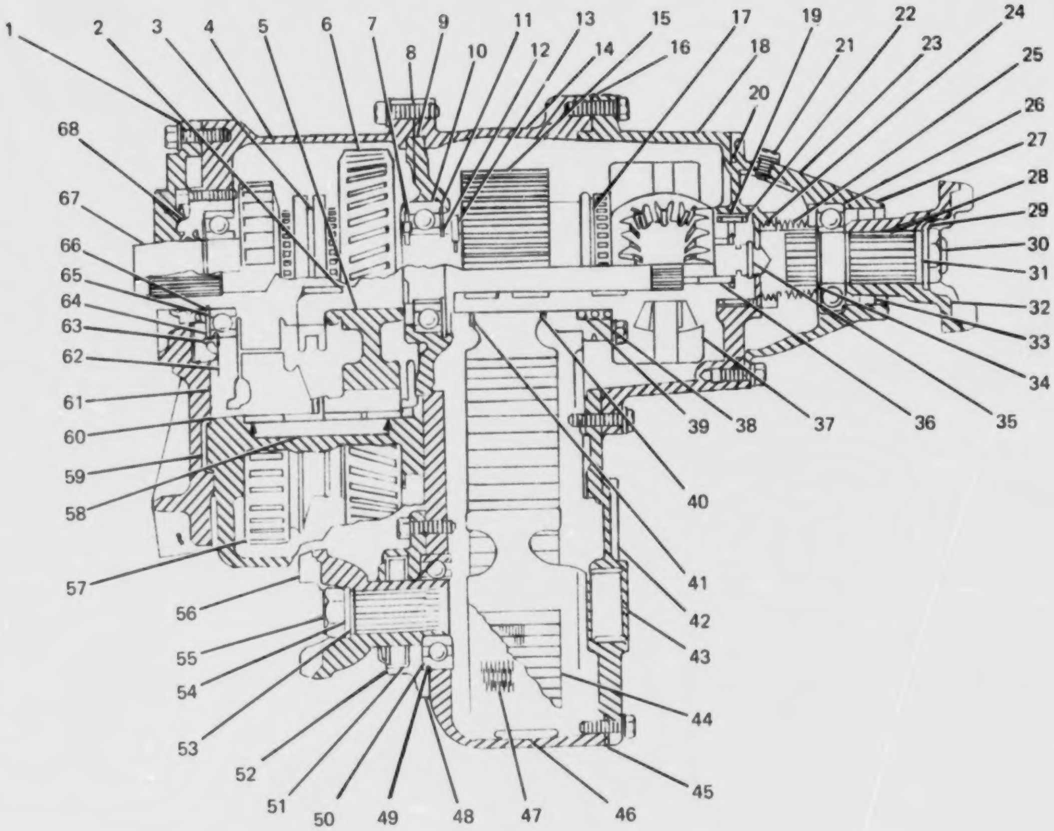
27-6. Operation (Fig. 27-5).

a. Unlocked. Engine torque is transmitted to the assembly through the input gear. In the high-range mode, engine torque is transmitted directly to the differential carrier, whereas in the low-range mode, engine torque is delivered to the differential carrier via the countergear and low-speed gear. Torque then is divided between the front and rear driving axles. Front axle torque is transmitted via a drive chain to the front output shaft. The rear-axle torque is transmitted directly to the rear output shaft from the differential carrier.

b. Locked (Fig. 27-5). When the transfer assembly is locked, the sliding lock clutch locks the differential carrier so that the front and rear output shafts will operate as a unit. All other power flow within the transfer assembly is the same as it is when the case is unlocked.

TA233764

572



1. ADAPTER
2. INPUT DRIVE GEAR PILOT BEARINGS
3. RANGE SELECTOR SLIDING CLUTCH
4. RANGE SELECTOR HOUSING
5. LOW-SPEED GEAR BUSHING
6. LOW-SPEED GEAR
7. THRUST WASHER AND LOCATING PIN
8. GASKET, RANGE SELECTOR HOUSING TO INTERMEDIATE HOUSING
9. INPUT BEARING RETAINER
10. INPUT BEARING
11. INPUT BEARING RETAINING RING (LARGE)
12. INPUT BEARING RETAINING RING (SMALL)
13. THRUST WASHER, LOCATING PIN, LUBRICATING WASHER AND RETAINING RING
14. INTERMEDIATE (CHAIN) HOUSING
15. DRIVE SHAFT SPROCKET
16. GASKET, INTERMEDIATE HOUSING TO DIFFERENTIAL HOUSING
17. SLIDING LOCK CLUTCH
18. DIFFERENTIAL HOUSING
19. REAR OUTPUT FRONT BEARING
20. O-RING, DIFFERENTIAL HOUSING TO REAR OUTPUT SHAFT HOUSING
21. VENT
22. OIL SEAL, REAR OUTPUT FRONT BEARING
23. OIL SEAL, VENT
24. OIL PUMP
25. SPEEDOMETER DRIVE GEAR
26. REAR OUTPUT REAR BEARING
27. REAR OUTPUT SHAFT HOUSING
28. REAR OUTPUT SHAFT
29. WASHER, REAR OUTPUT
30. NUT, REAR OUTPUT
31. RUBBER WASHER, REAR OUTPUT
32. REAR OUTPUT YOKE
33. OIL SEAL, REAR OUTPUT BEARING
34. SHIM PACK
35. INPUT SHAFT O-RING SEAL
36. INPUT SHAFT ROLLER BEARINGS
37. DIFFERENTIAL CARRIER ASSEMBLY
38. SPRING CUP WASHER
39. LOCKOUT CLUTCH SPRING
40. REAR RETAINING RING, DRIVE SHAFT SPROCKET
41. FRONT RETAINING RING, DRIVE SHAFT SPROCKET
42. FRONT OUTPUT REAR BEARING COVER
43. FRONT OUTPUT REAR BEARING
44. FRONT OUTPUT DRIVE SPROCKET
45. GASKET, FRONT OUTPUT REAR BEARING COVER
46. MAGNET
47. DRIVE CHAIN
48. GASKET, FRONT OUTPUT BEARING RETAINER
49. FRONT OUTPUT BEARING OUTER RETAINING RING
50. FRONT OUTPUT BEARING
51. FRONT OUTPUT SHAFT SEAL
52. FRONT OUTPUT BEARING RETAINER
53. RUBBER SPLINE SEAL
54. WASHER, FRONT OUTPUT
55. NUT, FRONT OUTPUT
56. FRONT OUTPUT YOKE
57. COUNTERGEAR
58. COUNTERGEAR SPACERS AND BEARINGS
59. COUNTERGEAR SHAFT
60. COUNTERGEAR THRUST WASHER
61. GASKET, ADAPTER TO SELECTOR HOUSING
62. GASKET, INPUT BEARING RETAINER
63. INPUT BEARING OUTER RING
64. INPUT GEAR BEARING
65. INPUT GEAR SEALS
66. INPUT BEARING RETAINING RING
67. INPUT GEAR
68. INPUT GEAR BEARING RETAINER

Figure 27-5. Differential-Type Transfer Assembly.

TA233765

515

Section IV. POSITIVE TRACTION TRANSFER CASE

27-7. Purpose. Some transfer assemblies contain an overrunning sprag unit (or units) on the front output shaft. On these units, the transfer is designed to drive the front axle slightly slower than the rear axle. During normal operation, when both front and rear wheels turn at the same speed, only the rear wheels drive the vehicle. However, if the rear wheels should lose traction and begin to slip, they tend to turn faster than the front wheels. As this happens, the sprag unit automatically engages so that the front wheels also drive the vehicle. The sprag unit simply provides an automatic means of engaging the front wheels in drive whenever additional tractive effort is required. There are two types of sprag-unit-equipped transfers: a single-sprag-unit transfer and a double-sprag-unit transfer. Essentially, both types work in the same manner.

27-8. Sprag-Unit Construction and Operation.

a. Transfer Assembly. The transfer assembly is very similar to that described in section II, the basic difference being that a sprag unit has been substituted for the hand-operated sliding clutch on the front output shaft. The sprag unit acts as an overrunning clutch, permitting the front wheels to turn freely at the same speed as the rear wheels, but locking up to drive the front wheels when the rear wheels tend to turn faster than the front wheels (as when the rear wheels lose traction and slip).

b. Sprag. A sprag (fig. 27-6) is a steel block shaped to act as a wedge in the complete assembly. In the sprag unit under discussion, there are 42 sprags assembled into an outer race and held in place by two energizing springs (fig. 27-6). The springs fit into the notches in the ends of the sprags and hold them in position. The outer race is in the driven gear on the front output shaft. The inner race is on the front output shaft itself.

27-9. Single-Sprag Unit (Fig. 27-7).

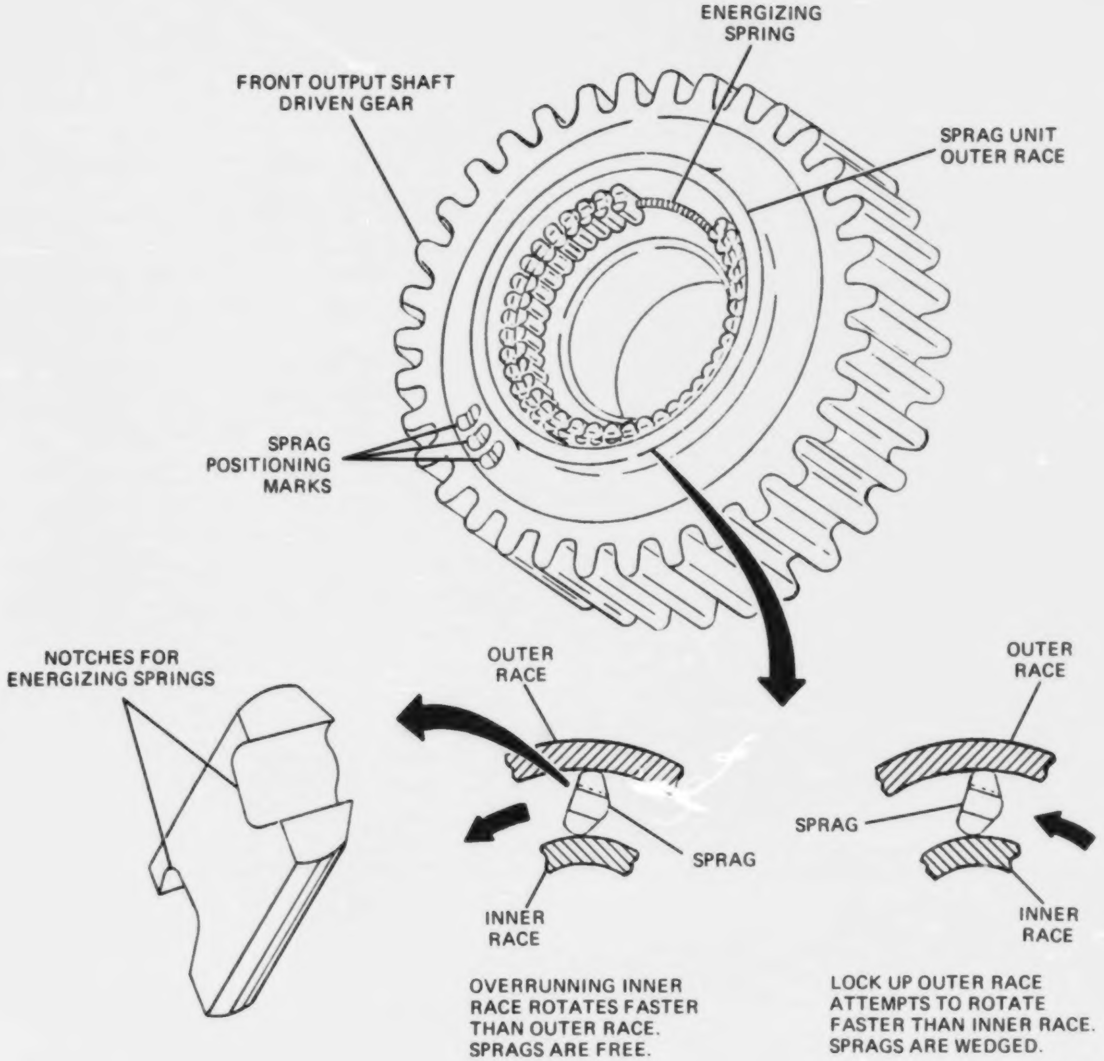
a. Forward. During normal operation, when front and rear wheels of the vehicle are turning at the same speed, the outer race of the sprag unit (in the driven gear) turns a little slower than the inner race (on the front output shaft). This prevents the sprags from wedging between the races. No lockup occurs and the front wheels turn freely; they are not driven. However, if the rear wheels should lose traction and tend to turn faster than the front wheels, the outer race tends to turn faster than the inner race. When this happens, the sprags wedge or jam between the two races and the races turn as a unit to provide driving power to the front wheels. Just as soon as the rear wheels regain traction so that they slow down to front-wheel speed, the outer race slows down in relation to the inner race and the sprag unit releases.

b. Reverse. In reverse, it is necessary to lock out the single-sprag unit, because rotation is reversed, and this means that no driving can be achieved through the sprag units at all.

Lockout is accomplished through a linkage to the transmission that shifts a reverse-shift collar in the transfer. As the reverse-shift collar is shifted, internal splines in the collar mesh with external splines on the reverse-shift driven gear and on the front output driven gear so there is a solid drive around the sprag unit.

27-10. Double-Sprag Unit.

a. Sprag Unit Operation. The double-sprag unit operates the same way as the single-sprag unit in forward speeds. In reverse, however, the difference between the two units becomes apparent. In the double-sprag unit, a second sprag unit has been included that comes into operation only in reverse. When the shift is made to reverse, the forward sprag unit is locked out, almost exactly as described in paragraph 27-9 for the single-sprag unit. However, the reverse sprag unit comes into operation. The front wheels drive in reverse when the rear wheels lose traction, and tend to revolve faster than the front wheels. The shift from one sprag unit to the other is accomplished by a linkage to the transmission that shifts a reverse-shift collar in the transfer. As the reverse-shift collar is shifted, internal splines in the collar unmesh from the external splines on the outer race of one sprag unit and mesh with the external splines on the other sprag unit.


ENERGIZING SPRING
FRONT OUTPUT SHAFT DRIVEN GEAR
SPRAG UNIT OUTER RACE
SPRAG POSITIONING MARKS
NOTCHES FOR ENERGIZING SPRINGS
OUTER RACE
SPRAG
INNER RACE
OUTER RACE
SPRAG
INNER RACE

OVERRUNNING INNER RACE ROTATES FASTER THAN OUTER RACE. SPRAGS ARE FREE.

LOCK UP OUTER RACE ATTEMPTS TO ROTATE FASTER THAN INNER RACE. SPRAGS ARE WEDGED.

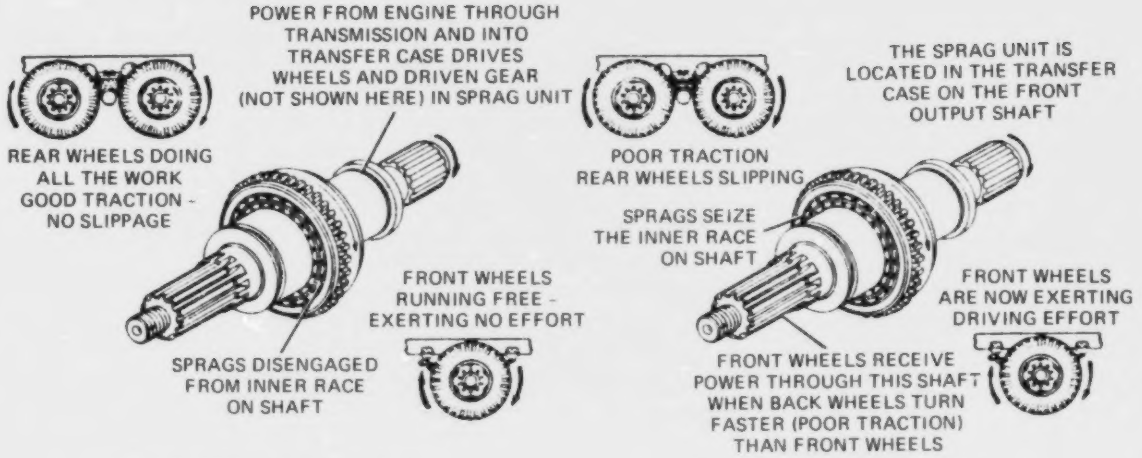
Figure 27-6. Transfer Assembly Sprag Unit.

b. Air-Operated Shift Control. Figure 27-7 shows the power flow in the transfer unit using the air-controlled double-sprag unit. The double-sprag unit has the same function as that described in paragraph 27-9, the basic difference being that there is an air valve on the transmission low- and reverse-shifter shaft, which automatically shifts the sprag unit to forward or reverse whenever the main transmission is shifted to forward or reverse.

c. Air-Operated Shifter Operation. Shown in figure 27-8 is the air-control diagram of the transmission and transfer assembly using an air-controlled double-sprag unit. When the transmission is in neutral or a forward gearshift position, and there is compressed air in the compressed air system of the vehicle, the air cylinder control valve (1, fig. 27-8) will be positioned to admit air under pressure from the compressed air system into the shift air cylinder assembly (8, fig. 27-8). The air then is admitted to the forward-shift side of the spring-balanced piston in the cylinder. The piston then is moved,

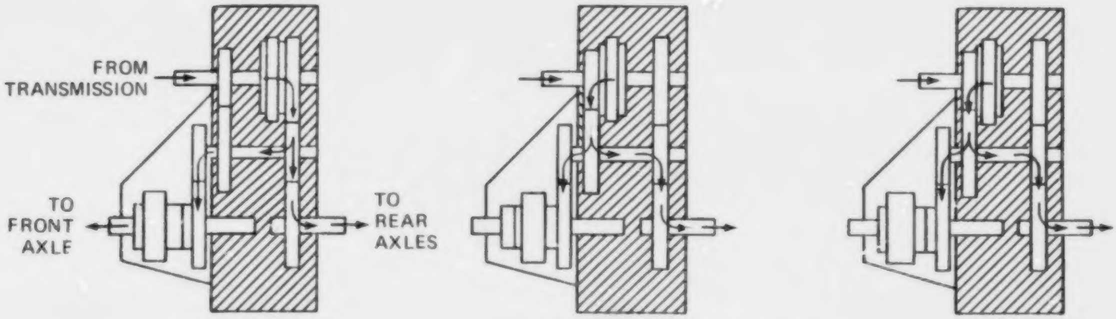
TA233766

517


POWER FROM ENGINE THROUGH TRANSMISSION AND INTO TRANSFER CASE DRIVES WHEELS AND DRIVEN GEAR (NOT SHOWN HERE) IN SPRAG UNIT
REAR WHEELS DOING ALL THE WORK GOOD TRACTION - NO SLIPPAGE
FRONT WHEELS RUNNING FREE - EXERTING NO EFFORT
SPRAGS DISENGAGED FROM INNER RACE ON SHAFT
THE SPRAG UNIT IS LOCATED IN THE TRANSFER CASE ON THE FRONT OUTPUT SHAFT
POOR TRACTION REAR WHEELS SLIPPING
SPRAGS SEIZE THE INNER RACE ON SHAFT
FRONT WHEELS ARE NOW EXERTING DRIVING EFFORT
FRONT WHEELS RECEIVE POWER THROUGH THIS SHAFT WHEN BACK WHEELS TURN FASTER (POOR TRACTION) THAN FRONT WHEELS

FRONT WHEELS RUNNING FREE

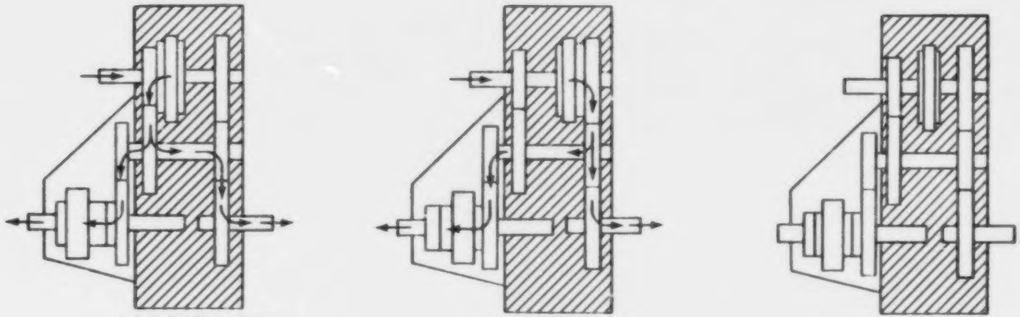
FRONT WHEELS DRIVING


FROM TRANSMISSION
TO FRONT AXLE
TO REAR AXLES

HIGH FORWARD

LOW REVERSE

LOW FORWARD



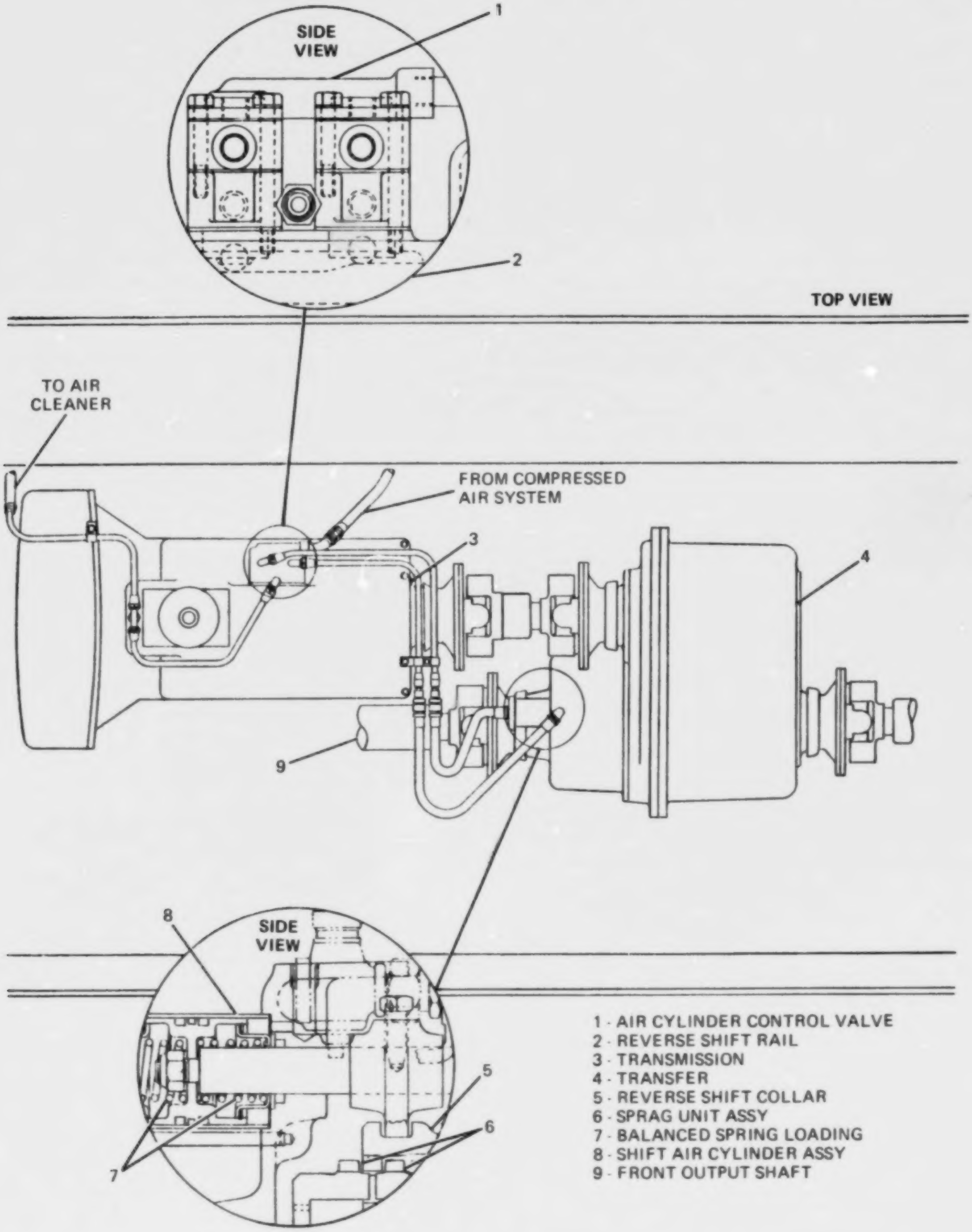
LOW FORWARD (WHEN BACK WHEELS SLIP)

HIGH REVERSE (WHEN BACK WHEELS SLIP)

NEUTRAL POSITION (NO AIR IN SYSTEM)

Figure 27-7. Positive Traction Transfer Case Operation.

TA233767


SIDE VIEW
1
2
TOP VIEW
TO AIR CLEANER
FROM COMPRESSED AIR SYSTEM
3
4
9
8
SIDE VIEW
5
6
7

1 - AIR CYLINDER CONTROL VALVE
2 - REVERSE SHIFT RAIL
3 - TRANSMISSION
4 - TRANSFER
5 - REVERSE SHIFT COLLAR
6 - SPRAG UNIT ASSY
7 - BALANCED SPRING LOADING
8 - SHIFT AIR CYLINDER ASSY
9 - FRONT OUTPUT SHAFT

Figure 27-8. Air-Control Diagram of Transmission and Transfer Assembly using an Air- Controlled Double-Sprag Unit.

TA233768

519

BEST COPY AVAILABLE

and causes engagement of the forward sprag unit. When the transmission is shifted into reverse, the air cylinder control valve admits air to the opposite side of the piston, causing engagement of the reverse sprag unit. When the forward sprag unit is engaged, the front wheels will freewheel or turn only in a forward direction. Likewise, if the reverse sprag unit is engaged, the front wheels cannot be turned in a forward direction. Also, if a vehicle with air pressure in the system is parked with the transmission shift lever in neutral position, it cannot be pushed backward until the transmission shift lever is shifted to reverse.

CHAPTER 28

PROPELLER SHAFTS, SLIP JOINTS, AND UNIVERSAL JOINTS

Section I. PROPELLER SHAFTS AND SLIP JOINTS

28-1. Propeller Shafts (Fig. 28-1).

a. Purpose. The power, having been transmitted through an angle by means of a universal joint, is next carried along the power train by a device known as a propeller, or drive, shaft. Propeller shaft is the most commonly used term; however, either may be used. In amphibious vehicles, both terms are used: propeller shaft, to indicate the device that transmits power to the propeller; and drive shaft, to indicate that which transmits power to the wheels.

b. Construction. Propeller shafts may be solid or tubular. The torsional stress in a shaft varies from zero at the axis to a maximum at the outside. Because the center of the shaft resists only a small portion of the load, hollow shafts are used wherever practicable. A solid shaft is somewhat stronger than a hollow shaft of the same diameter,

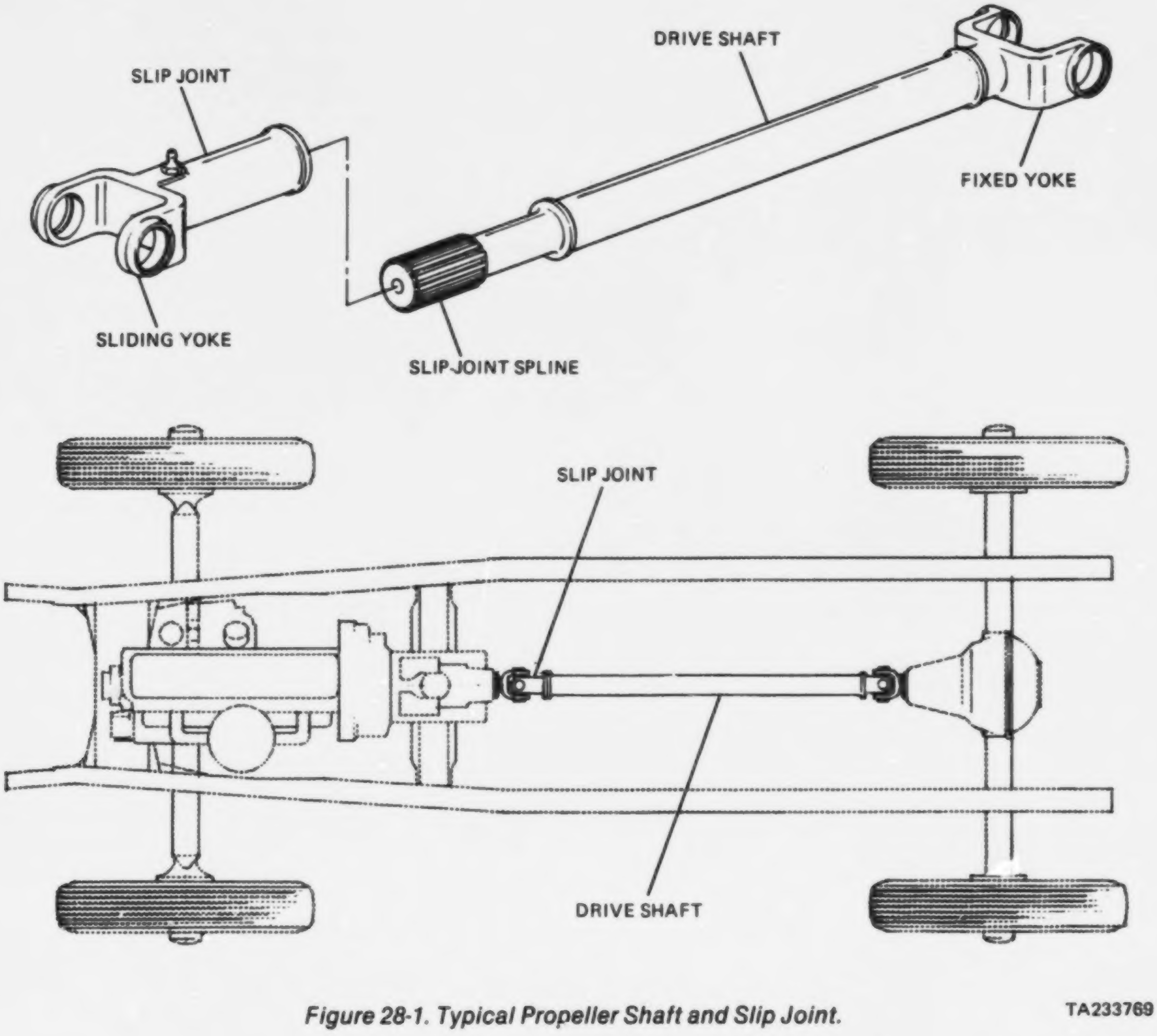


Figure 28-1. Typical Propeller Shaft and Slip Joint.

TA233769

but a hollow shaft is much stronger than a solid shaft of the same weight.

28-2. Slip Joints (Fig. 28-1).

a. Purpose. Because flexing of the springs causes the axle housing to move forward and backward, some provision must be made to allow the propeller shaft to contract and expand. A device known as a slip joint provides the necessary telescopic action for the propeller shaft.

b. Construction. A slip joint consists of a male and female spline, a grease seal, and a lubrication fitting. The male spline is an integral part of the propeller shaft and the female portion is fixed to the universal joint directly behind the transmission or transfer case. As the axle housing moves forward and backward, the slip joint gives freedom of movement in a horizontal direction and yet is capable of transmitting rotary motion.

Section II. CONVENTIONAL UNIVERSAL JOINTS

28-3. Purpose (Fig. 28-2). A universal joint is a flexible coupling between two shafts that permits one shaft to drive another at an angle to it. It is flexible in the sense that it will permit power to be transmitted while the angle between the shaft is being varied continually. A simple universal joint is composed of three fundamental units consisting of one journal and two yokes. The two yokes are set at right angles to each other, and their open ends are joined by the journal. This construction permits each yoke to pivot on the axis of the journal and also permits the transmission of the rotary motion from one yoke to the other. As a result, the universal joint can transmit the power from the engine through the shaft to the drive axle, even though the engine is mounted rigidly in the frame at a higher level than the axle, which is constantly moving up and down in relation to the frame.

28-4. Characteristics of Operation (Fig. 28-3). A peculiarity of the conventional universal joint is that it causes a driven shaft to rotate at a variable speed in respect to the driving shaft. It has been found that there is a cyclic variation, in the form of an acceleration and a deceleration of the speed, twice during each revolution. The extent of such fluctuation depends on the amount of angularity, roughly about 7 percent for an angle of 15 degrees, and about 30 percent for an angle of 30 degrees. This fact is shown graphically in figure 28-3, where the variations of the angular velocity during one revolution of a shaft driven through a conventional universal joint are plotted. The driving shaft is running at a constant velocity of 1,000 rpm, and the angle between the shafts is 30 degrees. Sketches of the universal joint positions at the minimum and maximum velocity fluctuation points are placed above the corresponding portions of the curve to enable the reader to correlate the curve with the action of the universal joint yoke and journal.

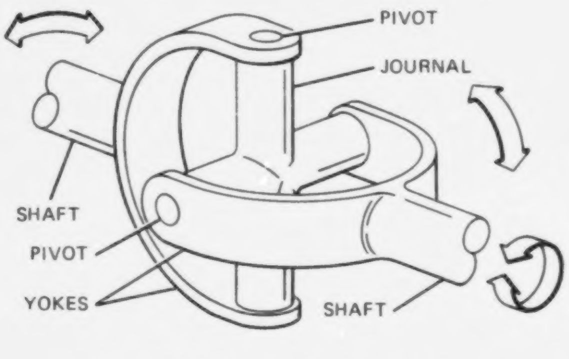
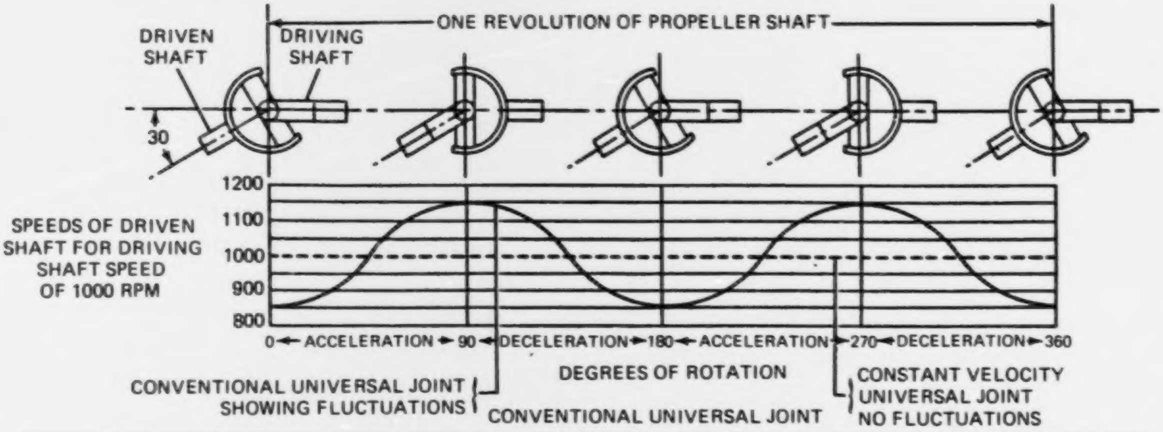


Figure 28-2. Typical Universal Joint.

a. In a quarter of a revolution, the speed of the driven shaft varies from a minimum of 866 to a maximum of 1,155 rpm. The speed of the driven shaft equals that of the driving shaft at four points during the revolution; that is, 45, 135, 225, and 315 degrees, where the curve intersects the constant velocity (dotted) line. The extent of each fluctuation depends on the size of the angle between the shafts; the greater the angle, the greater the variation in the speed of the two shafts.

b. This variation of velocity cannot be eliminated with a simple universal joint, but its effect can be minimized by using two universal joints, one at each end of the shaft. If only one joint is used between the transmission and the rear axle, the acceleration and deceleration caused by the joint is resisted on one end by the engine and on the other end by the inertia of the vehicle. The combined action of these two forces produces great stress on all parts of the power train and, in addition, results in a nonuniform force being applied to the wheels. When two universal joints

TA233770


ONE REVOLUTION OF PROPELLER SHAFT
DRIVEN SHAFT
DRIVING SHAFT
30
SPEEDS OF DRIVEN SHAFT FOR DRIVING SHAFT SPEED OF 1000 RPM
1200
1100
1000
900
800
0
ACCELERATION
90
DECELERATION
180
ACCELERATION
270
DECELERATION
360
DEGREES OF ROTATION
CONVENTIONAL UNIVERSAL JOINT SHOWING FLUCTUATIONS
CONVENTIONAL UNIVERSAL JOINT
CONSTANT VELOCITY UNIVERSAL JOINT NO FLUCTUATIONS

SHAFT ANGLE IN DEGREES	8	10	15	20	25	30	40
MAXIMUM VARIATION IN DRIVEN SHAFT SPEED PERCENT	2	3	6.9	12.4	19.7	28.9	54

Figure 28-3. Speed Fluctuations Caused by Conventional Universal Joints.

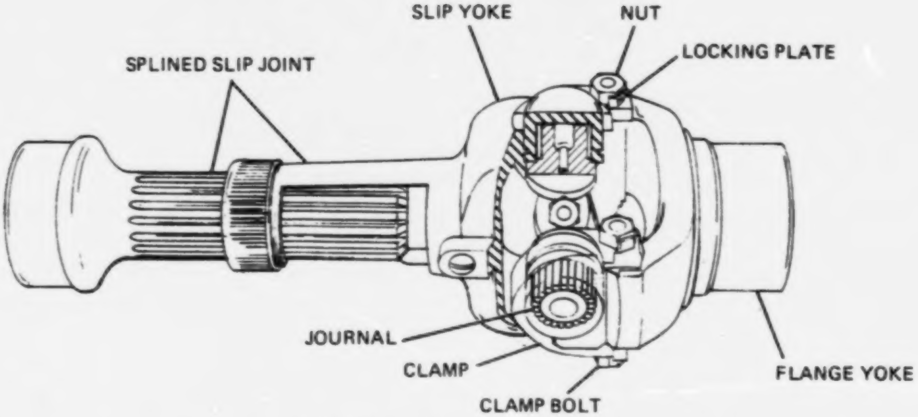
are employed, the second joint is used to compensate for the speed fluctuations caused by the first. In order to accomplish this, the angle between the transmission shaft and the propeller shaft must be the same as the angle between the propeller shaft and the final drive of the rear axle. Another requirement is that the two yokes of the universal joint that are attached to the propeller shaft be in the same plane. If the yokes of the joints attached to the propeller shaft are in the same plane, the driving yoke of the first joint will be at an angle of 90 degrees with the driving yoke of the second. The two yokes attached to the propeller shaft act as the driven yoke of the first joint and the driving yoke of the second joint, respectively. With this arrangement, the first joint is producing its maximum fluctuation at the same time the second joint is producing its minimum fluctuation. This results in a nonvarying wheel speed for a given engine speed, even though the speed of the shaft between the joints is changing constantly.

28-5. Types (Fig. 28-4). In an actual universal joint, bearings are included at the four points where the journal is attached to the yokes. In addition, one of the yokes usually incorporates a splined slip joint. In one type of universal joint (the ball-and-trunnion type), the universal joint itself incorporates a feature that permits variations in length of the propeller shaft.

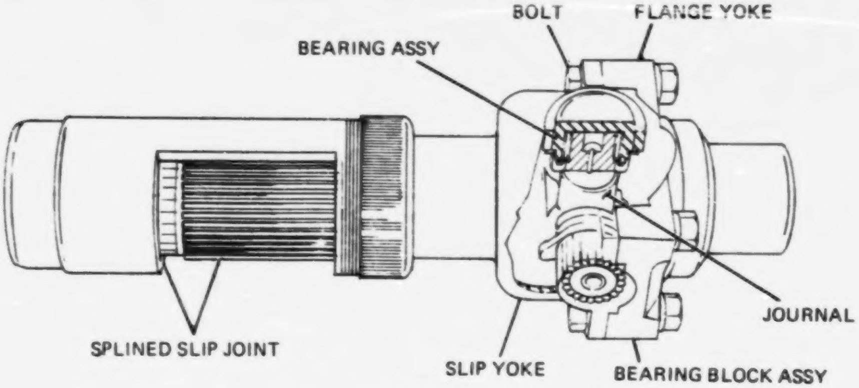
a. *Journal-Type Universal Joint.* There are several variations of this type of universal joint, two of which are shown in A and B, figure 28-4. The different universal joints of this type vary from each other mainly in the manner in which the journal is attached to the driving and driven yokes. For example, in the universal joint shown in A, figure 28-4, the journal is assembled in the shaft and slip yokes, the bearing assemblies inserted from the outside and secured by spring bearing retainers inside the yokes. The bearings on the transverse ends of the journal are clamped to the flange yokes and secured from outward movement by bearing retainers. The universal joint shown in A, figure 28-4, differs from that shown in B, figure 28-4, in the manner in which the journal is attached to the flange yoke. In this universal joint, the bearing assembly is contained in bearing blocks. The blocks are mounted against the flange yokes and secured with bolts extending longitudinally through the yokes.

b. *Ball and Trunnion.* Two universal joints of the ball-and-trunnion type are used in an application, one on each end of the propeller shaft. This type of joint is shown in C, figure 28-4. There is a trunnion pin through the end of the propeller shaft. The pin is fitted with balls that ride in grooves in the flanged body. The balls are assembled on bearings so they can rotate with little friction. Compensated springs at each end of

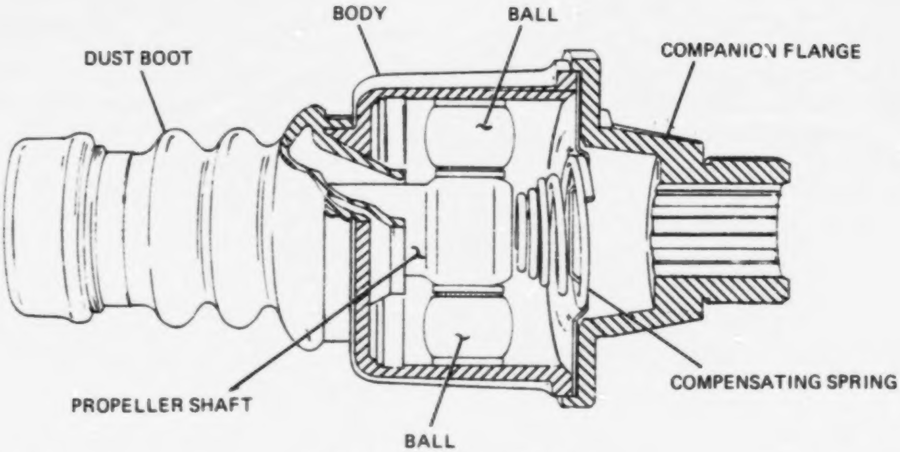
TA233771


SLIP YOKE
NUT
LOCKING PLATE
SPLINED SLIP JOINT
JOURNAL
CLAMP
CLAMP BOLT
FLANGE YOKE

A. JOURNAL TYPE


BOLT
FLANGE YOKE
BEARING ASSY
JOURNAL
SPLINED SLIP JOINT
SLIP YOKE
BEARING BLOCK ASSY

B. JOURNAL TYPE


BODY
BALL
DUST BOOT
COMPANION FLANGE
COMPENSATING SPRING
PROPELLER SHAFT
BALL

C. BALL-AND-TRUNNION TYPE

Figure 28-4. Various Conventional Universal Joints.

TA233772

the propeller shaft hold it in a centered position. Variations in length are permitted by the longitudinal movement of the balls in the body grooves, and angular displacement is allowed by outward movement of the balls on the trunnion pins. This type of universal joint is recognized easily by the flexible dust boot that covers it.

Section III. CONSTANT VELOCITY JOINTS

28-6. Characteristics of Operation.

a. The speed fluctuations caused by the conventional universal joints described in paragraph 28-5 do not cause much difficulty in automotive propeller shafts where they have to drive through small angles only. In front-wheel drives where the wheels are cramped up to 30 degrees in steering, velocity fluctuations present a serious problem. Conventional universal joints would cause hard steering, slippage, and tire wear each time the vehicle turned the corner. Constant-velocity universal joints, which eliminate the pulsations, are used exclusively to connect the front axle shaft to the driving wheels.

b. The conventional universal joint produces velocity fluctuations because the journal connecting the two yokes does not allow free movement other than a pivoting action. Velocity fluctuations occur because the journal tilts back and forth (wobbles) as the joint rotates. This tilting movement is translated into rotary movement and, when the journal tilts toward the output shaft, it adds to the speed of the output; and when the journal tilts away from the output shaft, it subtracts from the speed and the output shaft rotates slower than the input shaft. The only time that the speeds of the two shafts are equal is when the journal lies in the plane that bisects the angle between the two shafts. As stated in paragraph 28-5, this occurs only four times during each revolution.

c. It can be seen that a universal joint transmitting constant velocity must be designed to permit the point of driving contact between the two halves of the coupling to remain in a plane that bisects the angle between the two shafts. If this is accomplished, some arrangements must be made for the points of the driving contact to move laterally as the joint rotates. Keeping this in mind, it will be easier to understand the principles of constant-velocity joints that are in universal use today. Three types used in Army vehicles are: Rzeppa, Bendix-Weiss, and Tracta. These types are discussed separately to show that, in all, a plane passed through the points of the driving engagement will, at all times, bisect the angle between the driving and the driven shaft.

28-7. Types.

a. Rzeppa (Fig. 28-5). The Rzeppa joint is a ball-bearing type in which the balls furnish the only points of driving contact between the two halves of the coupling. The details of the component parts, adapted for use in a front driving axle, are shown in figure 28-5. The inner race (driving member) is splined to the inner axle shaft; the outer race (driven member) is a spherical housing that is an integral part of the outer shaft; the ball cage is fitted between the two races. The close spherical fit betweeen the three main members supports the inner shaft whenever it is required to slide in the inner race, relieving the balls of any duty other than the transmission of power. The movement of the six balls is controlled by the cage. The cage positions the balls in a plane at right angles to the two shafts when the shafts are in the same line. A pilot pin, located in the outer shaft, moves the pilot and the cage by a simple leverage in such a manner that the angular movement of the cage and the balls is one-half the angular movement of the driven shaft. When the driven shaft is moved 20 degrees, the cage and the balls move 10 degrees. As a result, the balls of the constant-velocity universal joint are positioned from the top view, to bisect the angle formed.

b. Bendix-Weiss (Fig. 28-6). The Bendix-Weiss joint also uses balls that furnish points of driving contact, but its construction differs from that of the Rzeppa in that the balls are a tight fit between the two halves of the coupling and no cage is used. The center ball rotates on a pin inserted in the outer race, and serves as a locking medium for the four other balls. The driving contact remains on the plane that bisects the angle between the two shafts, but it is the rolling friction between the four balls and the universal

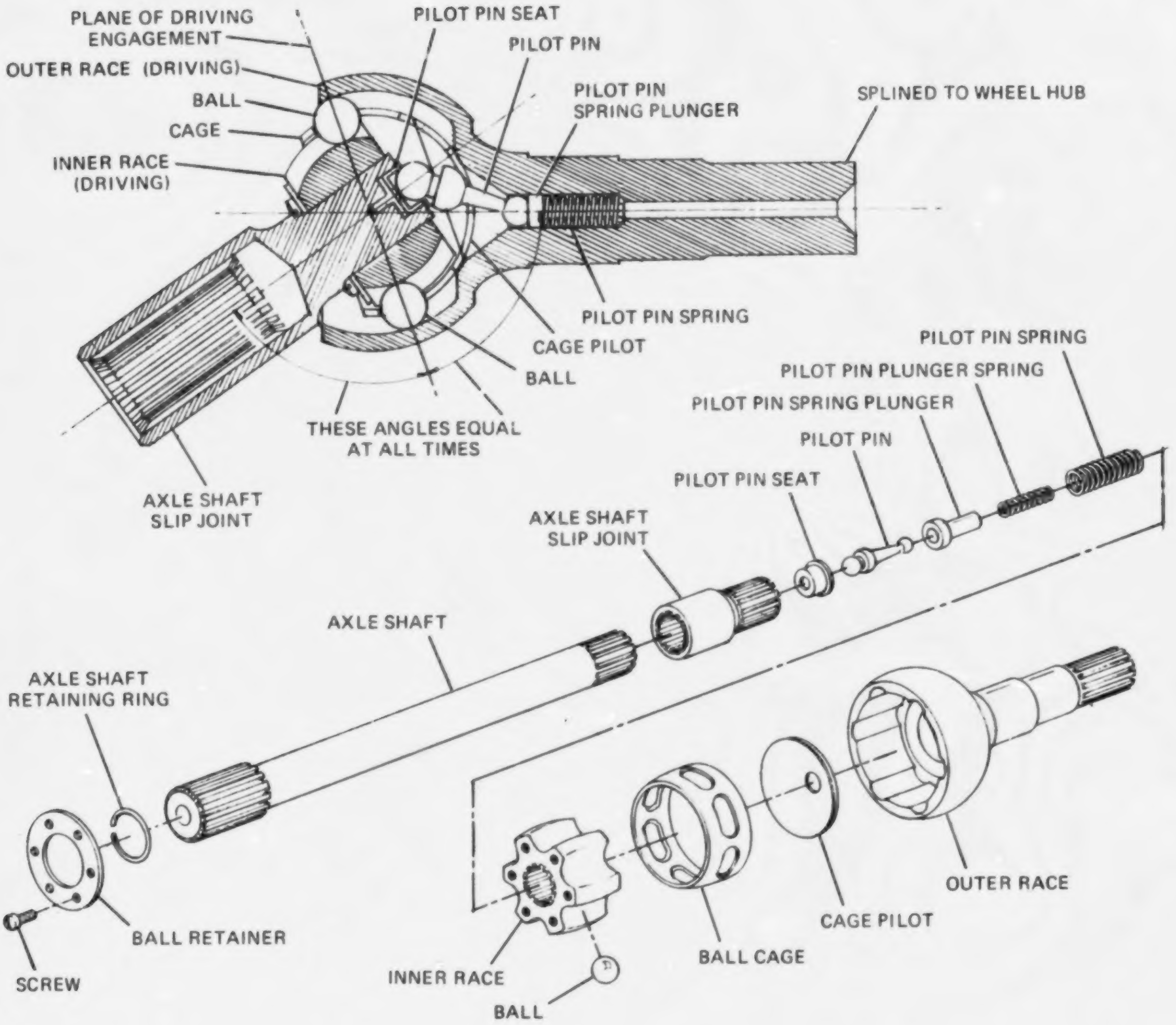

PLANE OF DRIVING ENGAGEMENT
OUTER RACE (DRIVING)
BALL
CAGE
INNER RACE (DRIVING)
PILOT PIN SEAT
PILOT PIN
PILOT PIN SPRING PLUNGER
SPLINED TO WHEEL HUB
PILOT PIN SPRING
CAGE PILOT
BALL
THESE ANGLES EQUAL AT ALL TIMES
AXLE SHAFT SLIP JOINT
PILOT PIN SPRING
PILOT PIN PLUNGER SPRING
PILOT PIN SPRING PLUNGER
PILOT PIN
PILOT PIN SEAT
AXLE SHAFT SLIP JOINT
AXLE SHAFT
AXLE SHAFT RETAINING RING
OUTER RACE
CAGE PILOT
BALL CAGE
BALL RETAINER
SCREW
INNER RACE
BALL

Figure 28-5. Rzeppa Constant Velocity Joint.

joint housing that positions the balls. The manner in which this action is accomplished can be illustrated by placing a ruler across a round pencil on a table; if the ruler is moved to cause the pencil to roll without slipping, the pencil travel is exactly half that of the ruler. In this example there are three objects: the table top, the pencil, and the ruler; two of which are movable members, and the third stationary. The inner race can be considered as the stationary table top, the ball as the pencil, and the driven race as the ruler. The same relative motion between the pencil and the ruler occurs between the outer (driven) race and the balls in the constant-velocity joint because the balls fit tight enough in the coupling to prevent slippage. The only difference is that motion of the pencil was limited to rolling in a direction perpendicular to the long axis of the pencil, whereas the balls may move in any direction. When both shafts of the constant-velocity joint are in line, that is, at an angle of 180 degrees, the balls lie in a plane that is at 90 degrees to the shafts. If it is assumed that the driving shaft remains in the original position, any movement of the driven shaft out of this line will cause the balls to move one-half the angular distance. Therefore, if the driven shaft moves through an angle of 20 degrees, the angle between the shafts will be reduced to 160 degrees, the balls will move 10 degrees in the same direction, and the angle between the driving shaft

TA233773

526

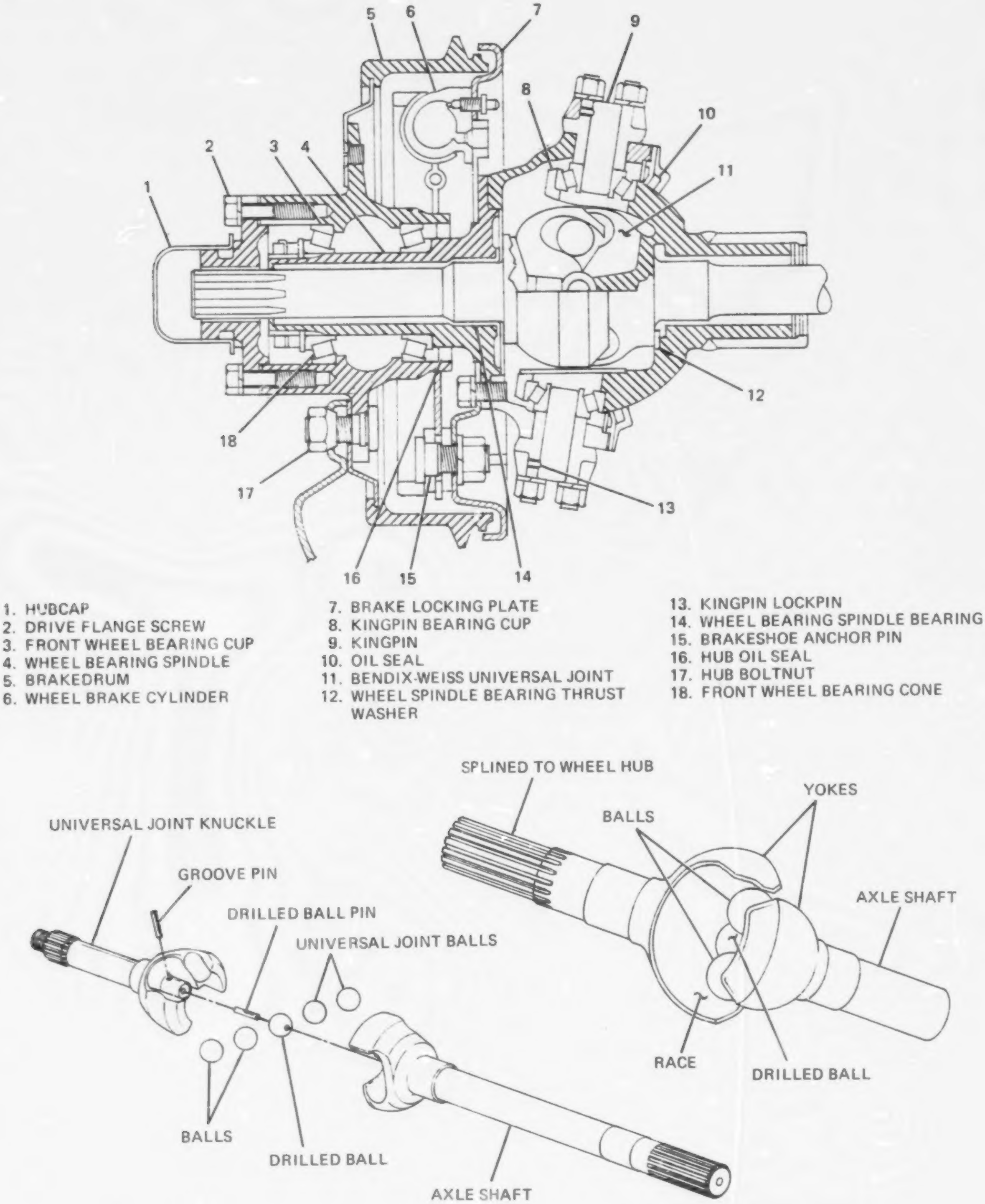

5
6
7
9
8
10
11
2
3
4
1
12
18
17
13
16
15
14
1. HUBCAP
2. DRIVE FLANGE SCREW
3. FRONT WHEEL BEARING CUP
4. WHEEL BEARING SPINDLE
5. BRAKEDRUM
6. WHEEL BRAKE CYLINDER
7. BRAKE LOCKING PLATE
8. KINGPIN BEARING CUP
9. KINGPIN
10. OIL SEAL
11. BENDIX-WEISS UNIVERSAL JOINT
12. WHEEL SPINDLE BEARING THRUST WASHER
13. KINGPIN LOCKPIN
14. WHEEL BEARING SPINDLE BEARING
15. BRAKESHOE ANCHOR PIN
16. HUB OIL SEAL
17. HUB BOLTNUT
18. FRONT WHEEL BEARING CONE
SPLINED TO WHEEL HUB
YOKES
BALLS
UNIVERSAL JOINT KNUCKLE
AXLE SHAFT
GROOVE PIN
DRILLED BALL PIN
UNIVERSAL JOINT BALLS
RACE
DRILLED BALL
BALLS
DRILLED BALL
AXLE SHAFT

Figure 28-6. Bendix-Weiss Constant Velocity Joint.

TA233774

and the plane in which the balls lie will be reduced to 80 degrees, fulfilling the requirement that the balls must lie in the plane that bisects the angle of drive.

c. Tracta Joint (Fig. 28-7). The Tracta universal joint is the simplest to install and service. It is, in effect, one universal joint within another, with points of driving contact on the outer portions of the joint. This universal joint consists of four main parts: a forked driving shaft, a forked driven shaft, a female (or slotted) joint, and a male (or spigot) joint. The complete inner joint, consisting of the female joint and the male joint, floats between the forks; movement between the individual halves of the inner joint is permitted in a direction perpendicular to that permitted by the slotted forks, by the action of the spigot moving in the slot. With this arrangement, the points of driving contact are allowed to move as the universal joint rotates, thereby remaining in a plane that bisects the angle between the two shafts. The fork ends subtend an angle greater than 180 degrees so as to be self-locking once the joint is assembled to the inner parts of the joint. A flat surface is milled on the cylindrical section of the joint to permit the joint to be inserted in place.

d. Double Cross and Roller (Fig. 28-8). The double cross and roller joint uses two cross and roller joints in tandem to form a single joint. The joints are linked through a centering yoke that works in conjunction with specially designed, spring-loaded centering ball. The components are contained within the center coupling yoke. As the shaft rotates, the action of the centering ball and yoke act to maintain an equally divided drive angle between the connected shafts, resulting in a constant drive velocity.

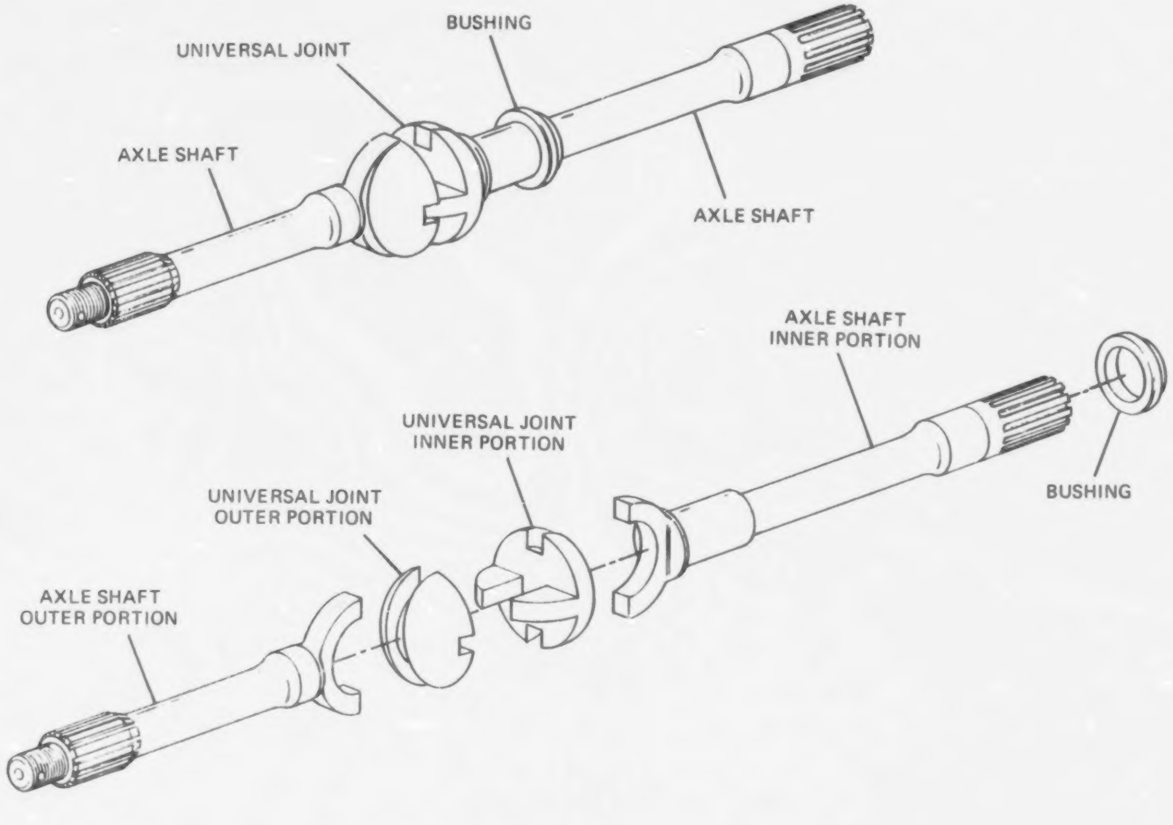


Figure 28-7. Tracta Constant Velocity Joint.

TA233775

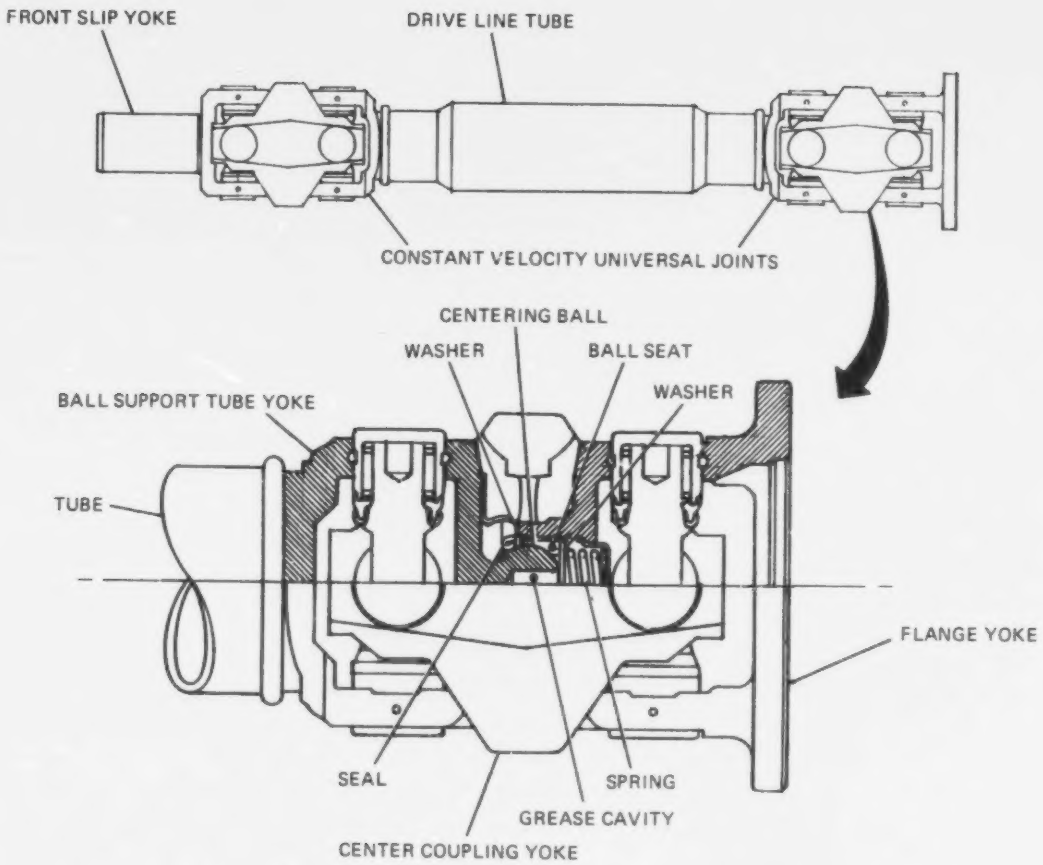

FRONT SLIP YOKE
DRIVE LINE TUBE
CONSTANT VELOCITY UNIVERSAL JOINTS
CENTERING BALL
WASHER
BALL SEAT
WASHER
BALL SUPPORT TUBE YOKE
TUBE
FLANGE YOKE
SEAL
SPRING
GREASE CAVITY
CENTER COUPLING YOKE

Figure 28-8. Double Cross and Roller Constant Velocity Joint.

TA233776

CHAPTER 29

DIFFERENTIALS, FINAL DRIVES, AND DRIVING AXLES

Section I. CONVENTIONAL DIFFERENTIALS

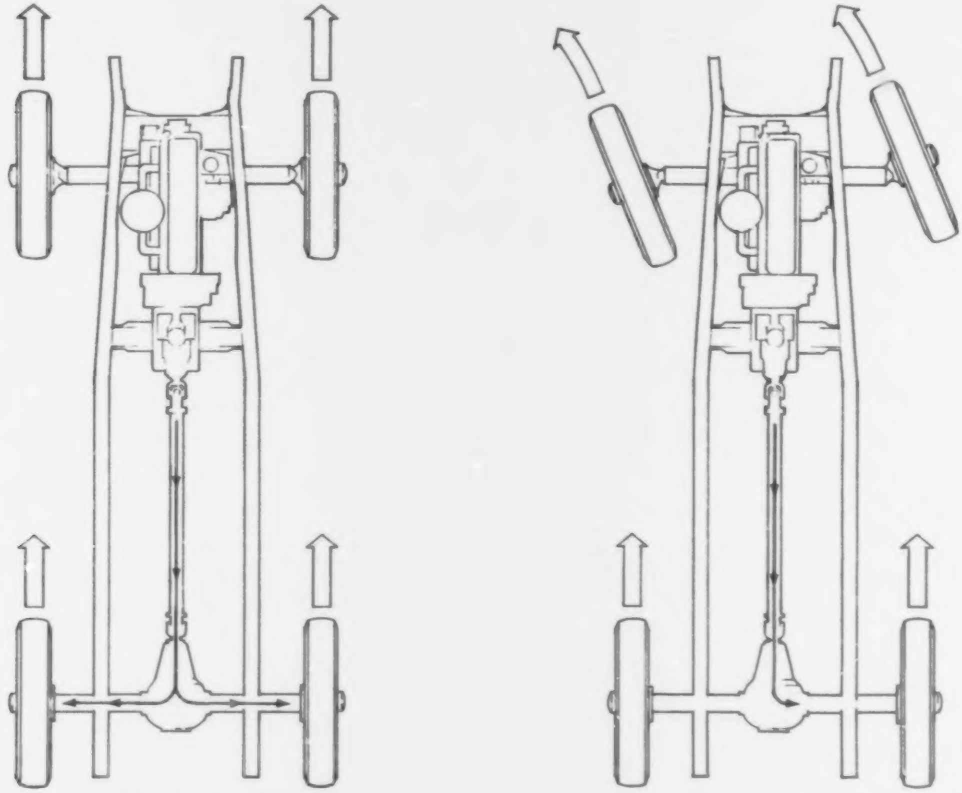
29-1. Purposes (Fig. 29-1).

a. Transmit Torque to Axles. One of the purposes of the differential is to transmit engine torque to the drive axles. The drive axles usually are on a rotational axis that is 90 degrees different than the rotational axis of the propeller shaft.

b. Divide Engine Torque. Another purpose of the differential is to divide engine torque between the driving wheels so that they are free to rotate simultaneously at varying speeds. This is important particularly if the vehicle is not moving in a straight line.

29-2. Principles of Operation (Fig. 29-2). The bevel drive pinion rotates the bevel drive ring gear and the differential case to which the final drive gear is bolted. The axle shafts are splined to the differential side gears. Were it not for the differential pinions, each wheel, with its respective axle shaft and side gear, would rotate freely with respect to the differential case and bevel drive gear.

a. Straight Ahead. When both wheels are rotating at the same speed, as they do on a smooth, straight road, the differential pinions do not rotate around their own axis but serve only to



TORQUE APPLICATION DURING STRAIGHT LINE MOTION

TORQUE APPLICATION DURING OPERATION AROUND CURVES

Figure 29-1. Differential Operation.

TA233777

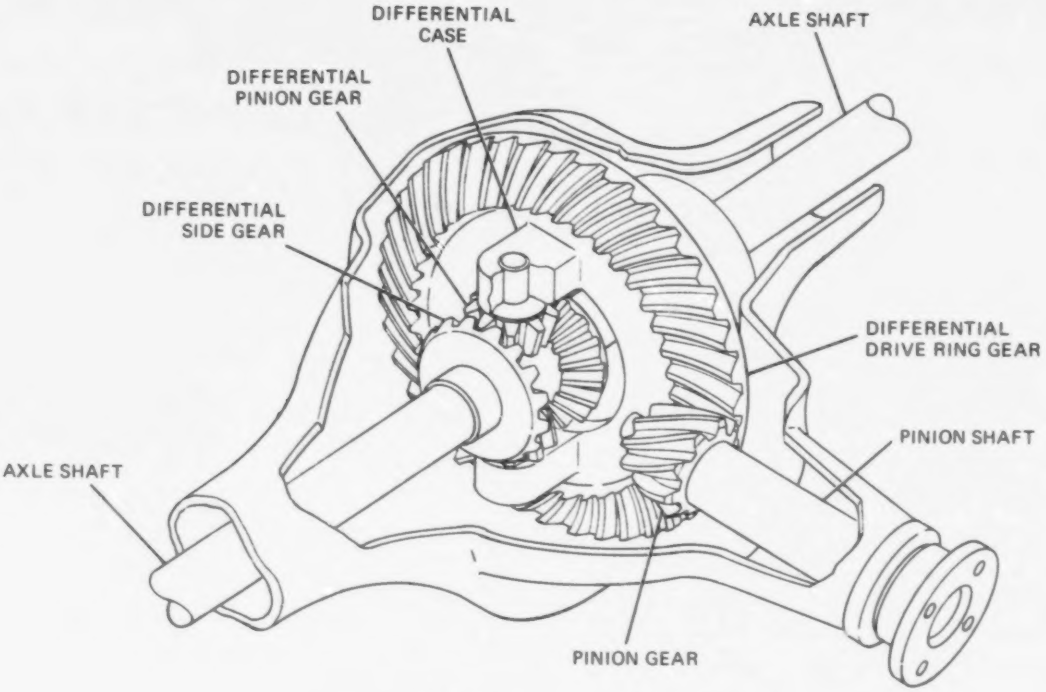


Figure 29-2. Conventional Differential.

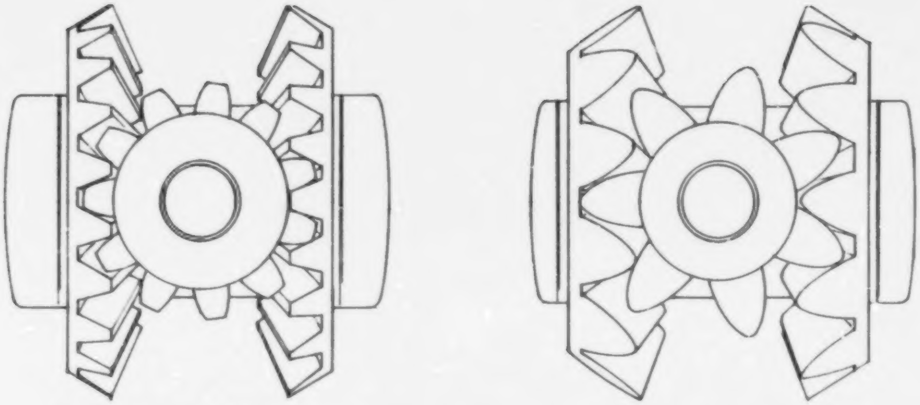
lock all the parts, making them rotate as a unit when the drive differential ring gear is turned by the differential drive pinion.

b. Turns. When the wheels rotate at different speeds, as they do when making a turn, the slowing down of the inner wheel decreases the rotation of its axle shaft and differential side gear with respect to the differential drive ring gear and the differential case. The case forces the differential pinions to rotate along the inner differential side gear, advancing the opposite side gear an equivalent amount with respect to the differential case. The outer wheel thus turns at a higher speed than the inner wheel. If the differential drive ring gear makes four revolutions while the inner wheel is making one, the outer wheel will rotate seven times.

29-3. High-Traction Differential Gears (Fig. 29-3). A fault in the conventional differential is that if one driving wheel loses traction and spins, the other wheel, which has more traction, remains stationary and does not drive the vehicle. In order to overcome this, several devices have been employed from time to time. One device is the hand-controlled differential lock. This is a dog clutch, controlled by a hand lever, that clutches one axle shaft fast to the differential case and differential drive ring gear. This forms a rigid connection between the two axle shafts and makes both wheels rotate at the same speed as the differential drive ring gear while the differential lock is engaged. This device is used very seldom, probably because a driver often forgets to disengage the differential lock before the differential action is required again.

Automatic devices for doing almost the same thing have been designed. One of these, which is used rather extensively today, is the high-traction differential. It consists of a set of differential pinions and side gears, which have fewer teeth, and a different tooth form from the conventional gears. Figure 29-3 shows a comparison between these and standard gears. These differential pinions and side gears depend on a variable radius from the center of the differential pinion to the point where it comes in contact with the side gear teeth, which is, in effect, a variable lever arm. As long as there is relative motion between the pinions and side gears, the torque is divided unevenly between the two driving shafts and wheels; whereas, with the usual differential, the torque is divided evenly at all times. With the high-traction differential, the torque becomes greater

TA233778



CONVENTIONAL DIFFERENTIAL
PINION AND SIDE GEARS

HIGH-TRACTION DIFFERENTIAL
PINION AND SIDE GEARS

Figure 29-3. Comparison of Conventional and High-Traction Differential Gears.

on one wheel and less on the other as the pinions move around, until both wheels start to rotate at the same speed. When this occurs, the relative motion between the pinion and side gears stops and the torque on each wheel is again equal. This device assists considerably in starting the vehicle or keeping it rolling in cases where one wheel encounters a slippery spot and loses traction while the other wheel is on a firm spot and has traction. It will not work, however, when one wheel loses traction completely. In this respect, it is inferior to the differential lock.

Section II. NO-SPIN DIFFERENTIALS

29-4. Purpose. To provide a means of improving tractive effort at the driving wheels when one wheel tends to slip from loss of traction, it is necessary that the differential prevent actual slippage and supply torque to the driving wheels only to the extent that the wheels can utilize the torque without slipping. The no-spin differential does this by using various types of clutches between the driving axles.

29-5. Sprag-Type No-Spin Differential (Fig. 29-4). The sprag-type no-spin differential does not contain pinion gears and side gears as does the conventional differential. Instead, it consists essentially of a spider attached to the differential drive ring gear through four trunnions, plus two driven clutch members with side teeth that are indexed by spring pressure with side teeth in the spider. Two side members are splined to the wheel axles and, in turn, are splined into the driven clutch members.

a. Operation in Turning. The center cam in the spider is held in place by a snapring that permits the center cam to rotate but does not permit it to move laterally. When making a right turn, the right-driven clutch member remains fully engaged with the spider clutch teeth. The spider clutch teeth (the driving teeth) drive the right (inside) wheel at differential drive ring gear speed. The left wheel (outside) covers a greater distance and must turn faster than differential drive ring gear speed. The differential must permit this action because, as the left wheel begins to turn faster, the left-driven clutch member also turns faster than differential drive ring gear and spider speed. As the left-driven clutch member begins to turn faster, the cam lobes or ramps on its edge ride up on the cam lobes on the center cam. This action pushes the left-driven clutch member away from the spider so the clutch teeth disengage. As the crest of the ramp is passed, spring pressure forces the teeth of the driven clutch member back into full engagement with the teeth on the spider. But the action is repeated as long as the left wheel turns more rapidly than the right wheel. Full drive is applied to the right wheel; no drive is applied to the left wheel. But as soon as the vehicle completes the turn and the left wheel slows down to right-wheel speed, driving power is applied equally to

TA233779

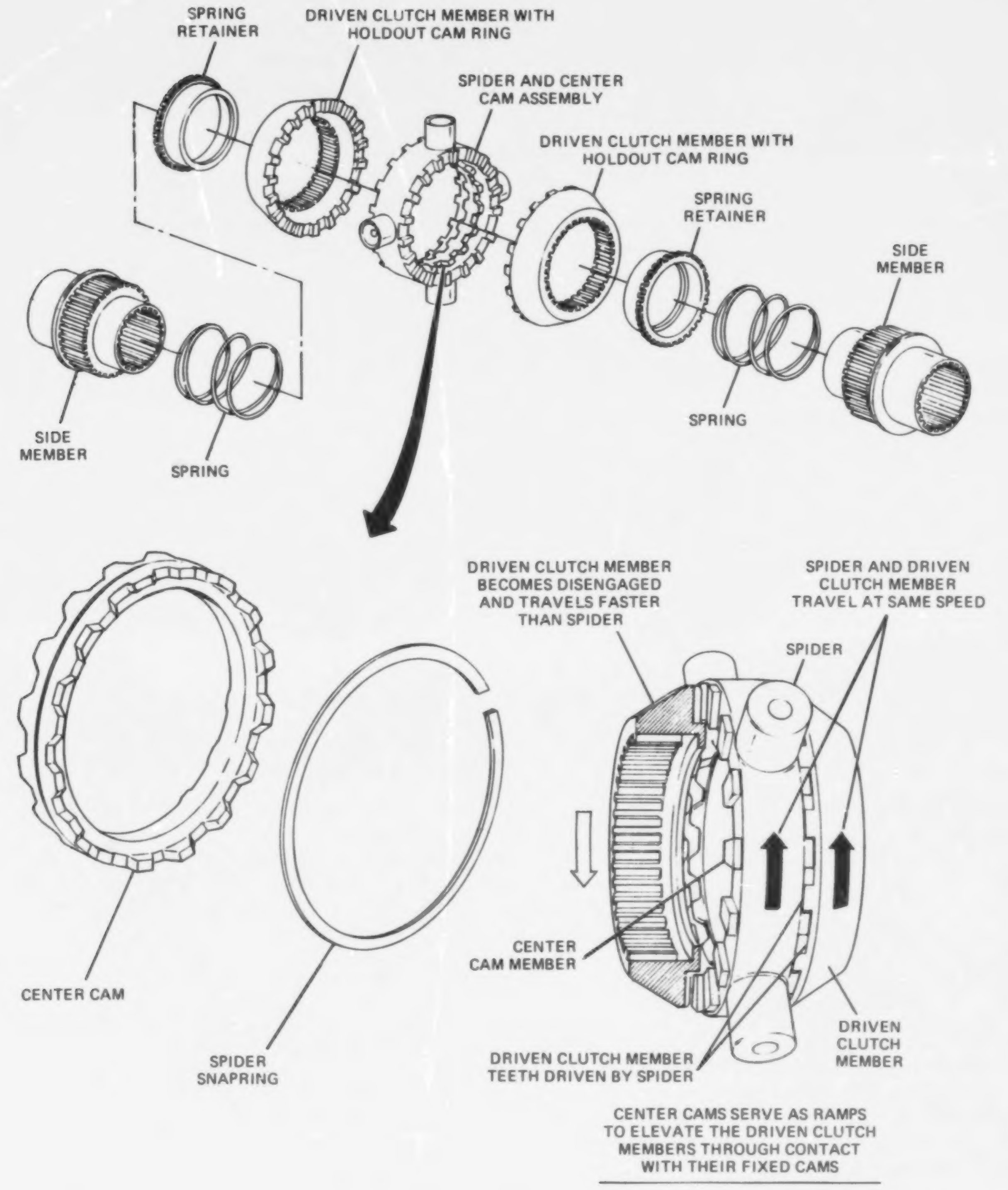

SPRING RETAINER
DRIVEN CLUTCH MEMBER WITH HOLDOUT CAM RING
SPIDER AND CENTER CAM ASSEMBLY
DRIVEN CLUTCH MEMBER WITH HOLDOUT CAM RING
SPRING RETAINER
SIDE MEMBER
SIDE MEMBER
SPRING
SPRING
DRIVEN CLUTCH MEMBER BECOMES DISENGAGED AND TRAVELS FASTER THAN SPIDER
SPIDER AND DRIVEN CLUTCH MEMBER TRAVEL AT SAME SPEED
SPIDER
CENTER CAM MEMBER
CENTER CAM
SPIDER SNAPRING
DRIVEN CLUTCH MEMBER TEETH DRIVEN BY SPIDER
DRIVEN CLUTCH MEMBER
CENTER CAMS SERVE AS RAMPS TO ELEVATE THE DRIVEN CLUTCH MEMBERS THROUGH CONTACT WITH THEIR FIXED CAMS

Figure 29-4. Sprag-Type No-Spin Differential.

TA233780

both. For a left turn, the action is similar except that full drive is applied to the left wheel; the right wheel turns more rapidly than the left wheel.

b. Tractive Effort. With this differential, one wheel cannot spin because of loss of tractive effort and thereby deprives the other wheel of driving effort. For example, one wheel is on ice and the other wheel is on dry pavement. The wheel on ice is assumed to have no traction. However, the wheel on dry pavement will pull to the limit of its tractional resistance at the pavement. The wheel on ice cannot spin because wheel speed is governed by the speed of the wheel applying tractive effort.

29-6. Silent-Type No-Spin Differential (Fig. 29-5). In the silent-type no-spin differential, the construction is very similar to the unit described above. However, the center cam has wider teeth to carry the two sets of cams in each driven clutch member. One set is fixed, the other is able to rotate in one direction or the other a few degrees with respect to the fixed set. The rotatable or holdout cam ring is slotted, and a key in the spider fits this slot to limit the independent rotation of the cam. The key also limits the rotation of the center cam. In operation, when one wheel is turning faster than the other (as in rounding a turn), the faster-turning splined side member and driven clutch member cause the ramps on the center cam and driven clutch member cam to push the driven clutch member away from the spider. This action is similar to that described above for the other no-spin differential. The teeth are separated so that no driving can take place. In this unit, however, the teeth do not index repeatedly because the rotatable cam, left slightly behind, prevents this. The ramps on the rotatable cam are halfway between the ramps on the fixed cam of the driven clutch member. The staggered ramps will not permit teeth engagement. As soon as the turn is completed, the driven clutch member slows down to spider speed, the ramps realine, and teeth engagement takes place.

Where a vehicle has a tandem driving axle unit or multiple axles, a no-spin differential may be placed in the transfer case between the output shafts to the driving axles. The differential prevents loss of tractive effort from slippage or tractive loss of one set of wheels. Also, it tends to balance torque and prevents interaxle trapped torque, which reduces total tractive effort.

29-7. Clutch-Type No-Spin Differential.

a. General. The clutch-type no-spin differential uses friction clutches to lock the axles together whenever one drive wheel experiences uncontrolled slippage. The clutch configurations that are used commonly are the cone or the multiple plate type.

b. Multiple Plate Clutch Type (Fig. 29-6). This type of no-spin differential uses four side gear pinions on two shafts that are at right angles to each other. The shafts, which are V-shaped on

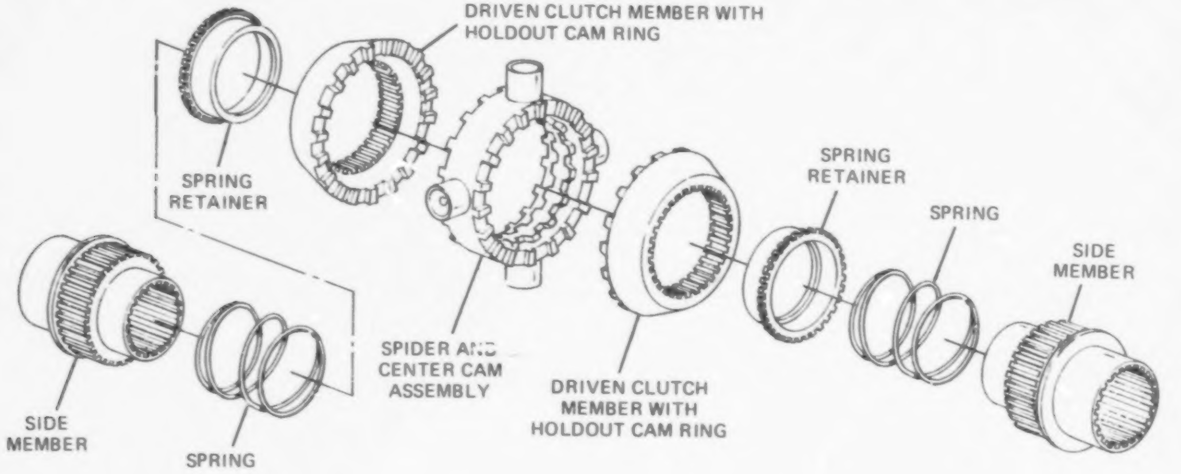
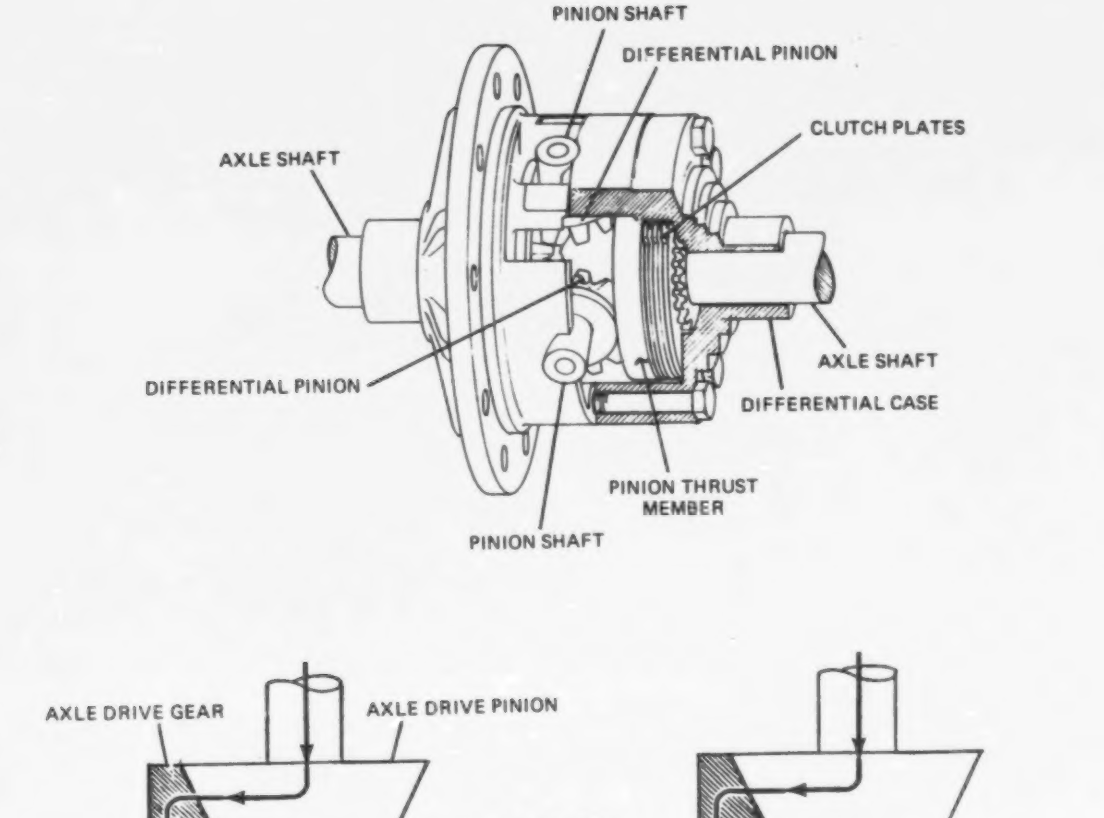

DRIVEN CLUTCH MEMBER WITH HOLDOUT CAM RING
SPRING RETAINER
SPRING RETAINER
SPRING
SIDE MEMBER
SPIDER AND CENTER CAM ASSEMBLY
DRIVEN CLUTCH MEMBER WITH HOLDOUT CAM RING
SIDE MEMBER
SPRING

Figure 29-5. Silent-Type No-Spin Differential.

TA233781

531


PINION SHAFT
DIFFERENTIAL PINION
CLUTCH PLATES
AXLE SHAFT
AXLE SHAFT
DIFFERENTIAL PINION
DIFFERENTIAL CASE
PINION THRUST MEMBER
PINION SHAFT
AXLE DRIVE GEAR
AXLE DRIVE PINION
DIFFERENTIAL CASE
CLUTCH PLATES
DIFFERENTIAL SIDE GEAR
AXLE SHAFT
AXLE SHAFT
DIFFERENTIAL PINION

A. STRAIGHT AHEAD

B. AROUND TURNS

Figure 29-6. Multiple Plate Clutch No-Spin Differential.

TA233782

their ends, engage similar V-shaped slots in the differential case. Each side gear is backed by a series of multiple disk clutches. Operation is as follows:

(1) *Straight Ahead (A, Fig. 29-6).* Whenever the differential case attempts to rotate the side gears through the side gear pinions and shafts, the shafts will slide up their V-shaped ramps and exert outward pressure. This outward pressure will tend to lock the side gears to the differential case through the clutches.

(2) *Around Corners (B, Fig. 29-6).* As the vehicle turns a corner, the inner drive wheel must slow down. The unequal speed between the side gears will cause the side gear pinions to walk around the side gears. This walking will cause the outer axle shaft to rotate faster than the differential case, allowing the pinion shaft on that side to slide down its ramp. This releases the outer clutches, causing the differential to act like a conventional unit.

c. Cone Clutch Type (Fig. 29-7). The cone clutch no-spin differential uses two spirally grooved cones that fit into the housing. These cones fit behind the side gears and are splined to the axle shafts. Coil springs are situated between the side gears to wedge the clutches into the case.

(1) *Straight Ahead.* In a straight-ahead position, the axle shafts will turn at the same speed, and operation virtually will be the same as a conventional differential.

(2) *Around Corners.* Around a corner, the inner drive wheel must slow down. The unequal speed between the side gears will cause the side gear pinions to walk around the side gears. This walking will cause the outer axle shaft to rotate faster than the differential case. Because the cones have spiral grooves cut into their clutch surfaces, the inner cone clutch will draw itself into the case and lock tight and the outer cone clutch will back itself out of the case and allow the outer drive axle to freewheel. The end result is the majority of the engine torque being sent to the inner drive wheel.

(3) *Slippage of One Wheel.* If one wheel loses traction, all engine torque will be transfered

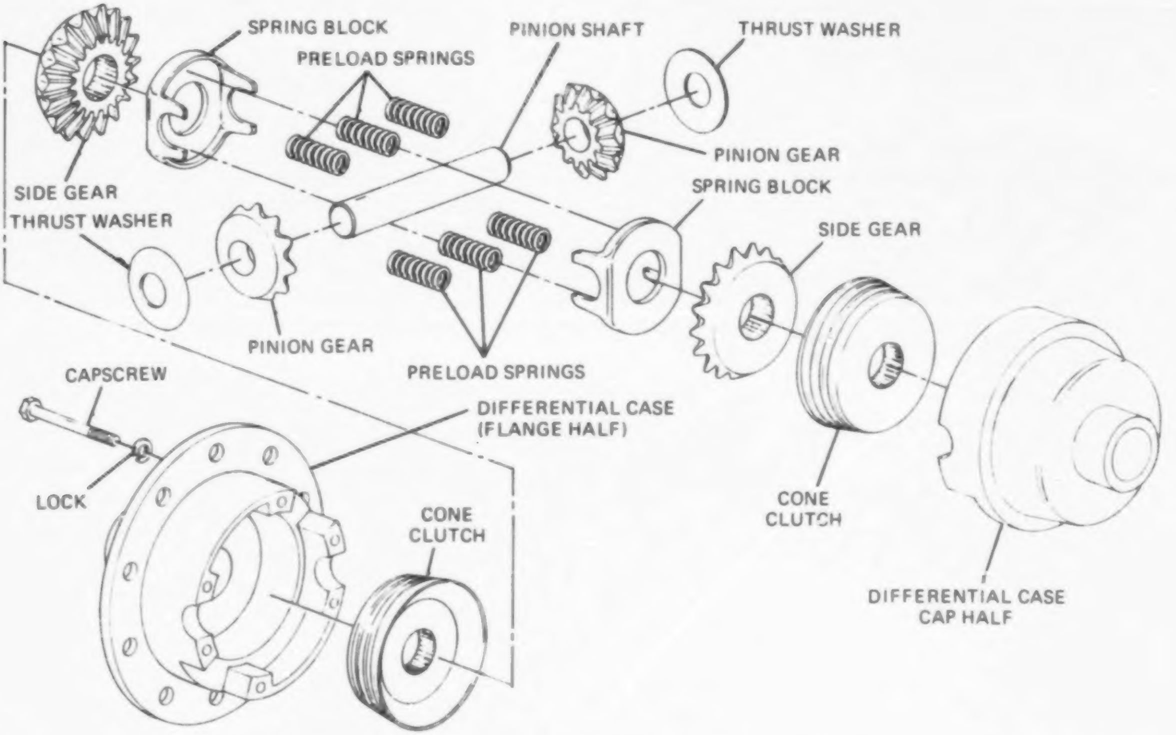

SPRING BLOCK
PRELOAD SPRINGS
PINION SHAFT
THRUST WASHER
PINION GEAR
SPRING BLOCK
SIDE GEAR
SIDE GEAR
THRUST WASHER
PINION GEAR
PRELOAD SPRINGS
CAPSCREW
DIFFERENTIAL CASE (FLANGE HALF)
LOCK
CONE CLUTCH
CONE CLUTCH
DIFFERENTIAL CASE CAP HALF

Figure 29-7. Cone Clutch-Type No-Spin Differential.

TA233783

immediately to the opposite wheel via the cone clutches.

(4) *Slippage of One Wheel in Reverse.* Because the spiral grooves that are cut into the cone clutches are directional, the cone clutch no-spin differential will not work in reverse because the cone clutches will unscrew themselves from the case, causing the no-spin feature to be inoperative.

Section III. FINAL DRIVES AND DRIVING AXLES

29-8. Overview.

a. A final drive is that part of a power transmission system between the propeller shaft and the differential. Its function is to change the direction of the power transmitted by the propeller shaft through 90 degrees to the driving axles. At the same time, it provides a fixed reduction between the speed of the propeller shaft and the axle driving the wheels. In passenger cars, this speed reduction varies from about 3:1 to 5:1. In trucks, it varies from about 5:1 to 11:1.

b. The gear ratio of the bevel gear final drive is found by dividing the number of teeth on the bevel drive gear by the number of teeth on the pinion. For a worm gear, it is found by dividing the number of teeth on the worm gear by the number of threads on the worm. In the case of chain drives, the sprockets are considered gears, and the number of teeth on the driven sprocket is divided by the number of teeth on the driving sprocket.

29-9. Gear Drives.

a. General (Fig. 29-8). All the final drives in general use are geared. The most common of these consists of a pair of bevel gears; that is, a drive pinion connected to the propeller shaft and a bevel drive gear attached to the differential case on the driving axle. These bevel gears may be spur, spiral-bevel, or hypoid. Spur gears have straight teeth, while spiral-bevel and hypoid

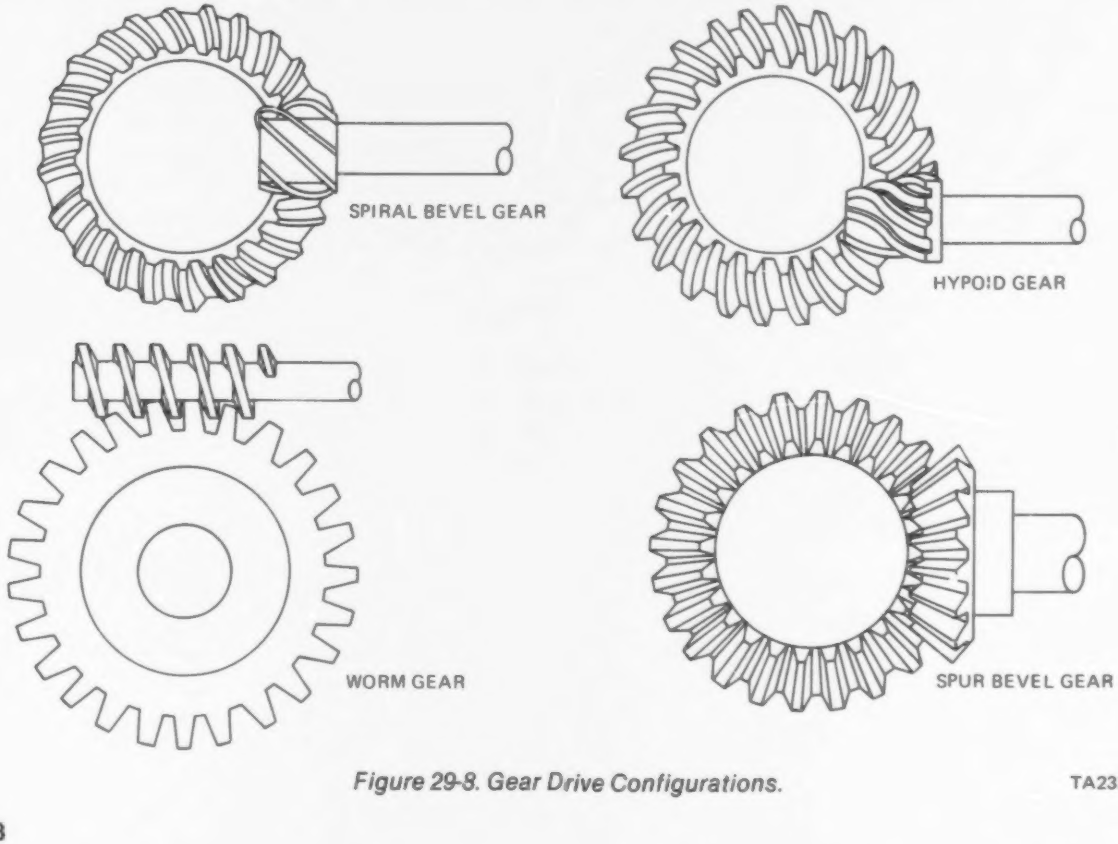


Figure 29-8. Gear Drive Configurations.

TA233784

gears have curved teeth. Spur gears are used very little for this purpose because they are noisy. Spiral-bevel gears are used most often. Hypoid gears are used in several passenger cars and in light trucks because they permit the bevel drive pinion to be placed below the center of the bevel drive gear, thereby lowering the propeller shaft to give more body clearance. This gear also operates more quietly. Worm gears are used extensively in trucks because they allow a large speed reduction. These consist of helical worm, similar to screws, and meshing teeth gears. The worms have single, double, triple, or quadruple threads. These type gears are shown in figure 29-8. Internal gear drives were once popular and still are used in rare instances. They permit a large speed reduction like the double chain drive, which they resemble. A jackshaft is driven by the propeller shaft through bevel gears and the differential as it is in the double-chain drive, except that the jackshaft is mounted on the dead rear axle and parallel to it. Spur pinions keyed on the ends of the jackshaft drive internal gears attached to the wheels. The first gear reduction takes place in the bevel pinion and differential drive ring gear and the second in the internal gears.

b. Worm (Fig. 29-9). The worm gear rear axle is used in some trucks because it allows a large speed reduction. The threads on the worm are similar to screw threads and may be single, double, triple, or quadruple. The worm meshes with a worm gear having helical teeth cut in its outside circumference. The worm may be compared to a screw and the worm gear to a nut. As the worm rotates, it pulls the worm gear around. The worm usually is made of steel and the worm gear of bronze. The driving worm may be mounted at either the top or the bottom of the worm gear. But, usually it is necessary to place the worm at the top in order to allow sufficient road clearance under the rear axle housing. The rear worm bearing must be very strong and rugged because it takes the entire thrust reaction from driving the worm gear. If play develops in the worm because of wear, this bearing also must withstand repeated impact. When the vehicle is operated in reverse, or when the road wheels are driving the mechanism, the front bearing resists these forces. Sometimes a worm of hourglass form is used in the worm gear as it provides more tooth bearing surface and, consequently, less stress in the teeth.

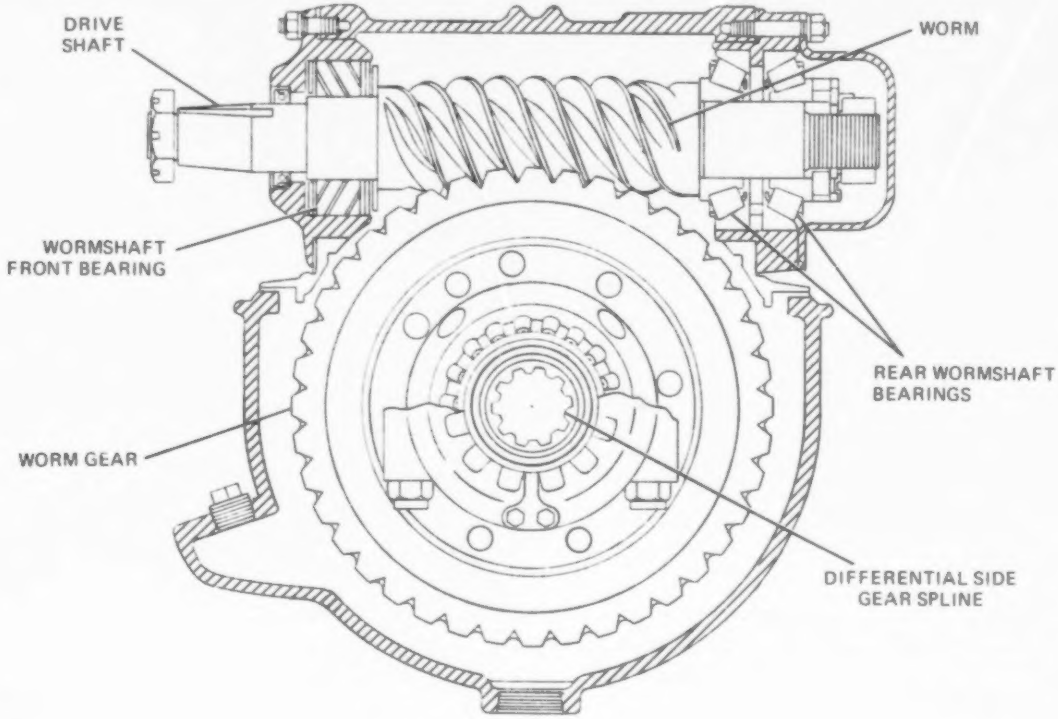


Figure 29-9. Worm Gear Drive.

TA233785

c. Hypoid (Fig. 29-10). Hypoid gearing has come into rather extensive use recently, mainly for passenger cars. A portion of a hypoid rear axle is shown in figure 29-10. This rear axle is almost the same as the spiral-bevel gear rear axle, except that the drive pinion and bevel drive gear are cut with a somewhat different tooth form, which permits the drive pinion to mesh with the bevel drive gear below the center of the latter. This construction allows the propeller shaft to be lowered and sometimes makes a shaft tunnel in the floor of the rear compartment of the vehicle unnecessary. Due to their design, hypoid gears operate under extremely high tooth pressure and require a special hypoid lubricant.

29-10. Live Axle Configurations.

a. General. A live axle is one that supports part of the weight of a vehicle and also drives the wheels connected to it. The term is applied to the entire assembly, which consists of a housing containing a bevel drive pinion, bevel drive gear differential and axle shafts together with their bearings, and sometimes additional mechanisms. The term live axle is opposed to the term dead axle. A dead axle is one that carries part of the weight of a vehicle but does not drive the wheels. The wheels rotate on the ends of the dead axle. The usual front axle of a passenger car is a dead axle and the rear axle is a live axle. In four-wheel drive vehicles, both front and rear axles are live axles, and in six-wheel drive vehicles all three axles are live axles.

b. Plain (A, Fig. 29-11). The plain, or nonfloating, rear axle was one of the first used. In it, the axle shafts are supported in the housing by roller bearings at the center and outer ends. The rear wheels are keyed on tapers at the outer ends of the axle shafts and held by castle nuts and cotter pins. In addition to turning the wheels, the rotating axle shafts carry the entire weight of the rear of the vehicle on their outer ends. All stresses caused by turning corners, skidding, or by wobbling wheels are taken by the axle shafts. The differential side gears are keyed on the inner ends of the axle shafts, which carry the weight of the differential case. The stresses created by the operation of the differential are taken by the axle shafts. Side thrust on the axle shafts is taken care of by the roller bearings, and ball bearings are provided at each side of the differential case to take care of end thrust. This type of rear axle is obsolete now.

c. Semifloating (B, Fig. 29-11). The semifloating rear axle is used on most passenger and light commercial vehicles. The principal difference between it and the plain live axle is in the manner of supporting the differential assembly. In the plain live axle, the differential case is carried on the inner ends of the axle shafts. In the semifloating axle, it is carried by bearings mounted in the differential carrier. The axle shafts are splined to the differential side gears. This relieves the axle shafts of the weight of the differential and the stresses caused by its operation that are taken by the axle housing. The inner

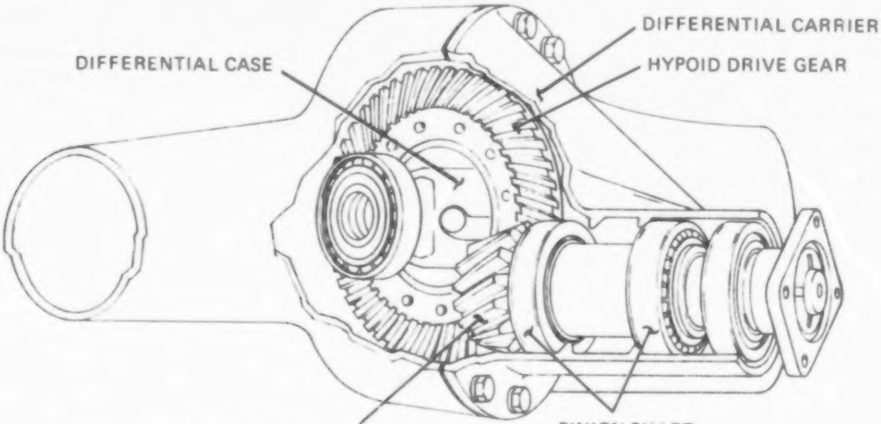
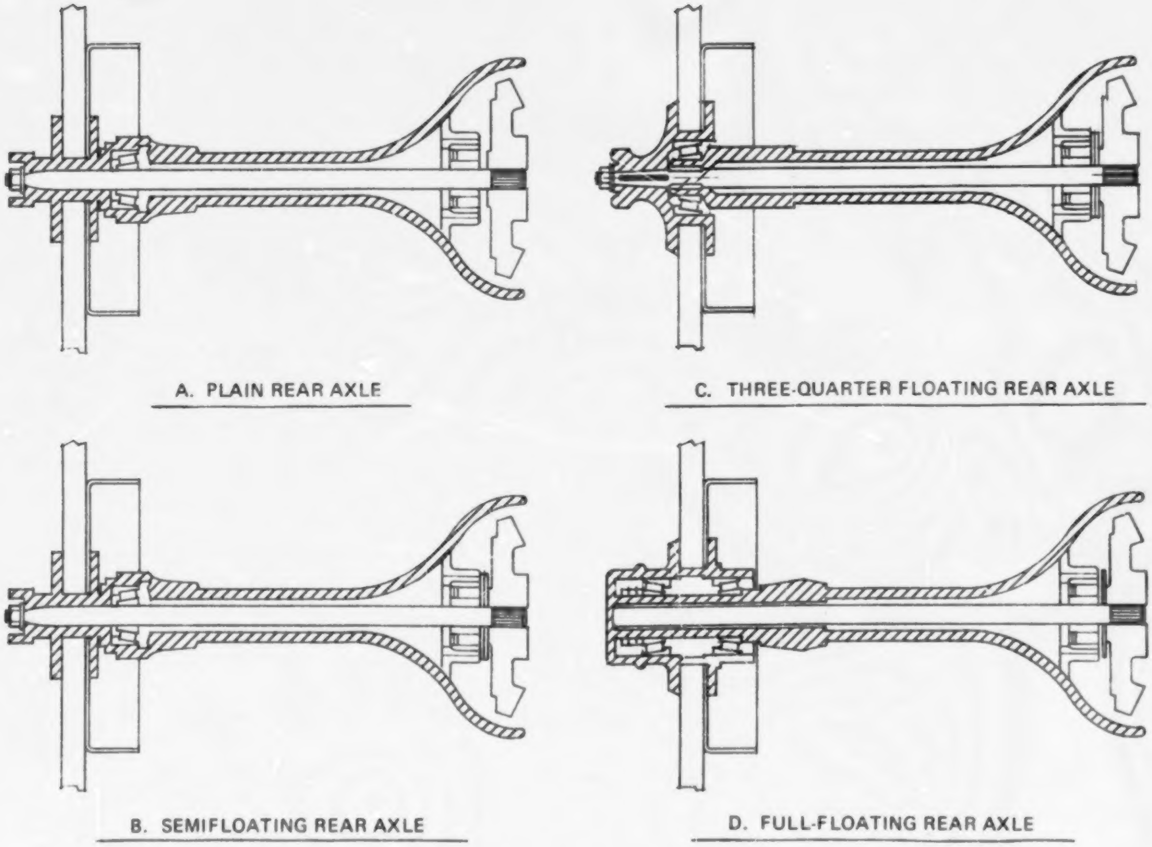


Figure 29-10. Hypoid Gear Drive.

TA233786

539



A. PLAIN REAR AXLE

B. SEMIFLOATING REAR AXLE

C. THREE-QUARTER FLOATING REAR AXLE

D. FULL-FLOATING REAR AXLE

Figure 29-11. Axle Configurations.

ends of the axle shafts transmit only turning effort, or torque, and are not acted upon by any other force. They are said to be floated. The wheels are keyed to the outer ends of the axle shafts, and the outer bearings are between them and the housing, as in the plain live axle. The axle shafts take the stresses caused by turning, skidding, or wobbling of the wheels. In both the plain and semifloating live axles, a wheel can come off if an axle shaft breaks or twists off.

d. Three-Quarter Floating (C, Fig. 29-11). The three-quarter floating rear axle is used on a few passenger cars. The inner ends of the axle shafts sometimes are secured with nuts and the axle shafts cannot be withdrawn without removing the differential cover. In other designs, the axle shaft can be withdrawn after the nuts holding the hub flange have been removed. The wheels, however, are supported by bearings on the outer ends of the axle tubes. The housing, instead of the axle shafts, carries the weight of the car. Because the wheel is keyed rigidly on a taper at the end of the axle shaft, as in the semifloating axle, the stresses caused by turning, skidding, and wobbling of the wheels still are taken by the axle shaft.

e. Full Floating (D, Fig. 29-11). The full-floating rear axle is used on most heavy trucks. It is the same as the three-quarter floating axle, except that each wheel is carried on the end of the axle tube on two ball or roller bearings and the axle shafts are not connected rigidly to the wheels. Each wheel is driven through a dog clutch, through a spline clutch, or through a flange on the end of the axle shaft that is bolted to the outside of the wheel hub. The latter construction is used frequently but is not truly full floating, because there is a rather rigid connection between the axle shaft and the wheel hub. With the true full-floating axle, the axle shaft transmits only the turning

TA233787

effort or torque. The stresses caused by turning, skidding, and wobbling of the wheels are taken entirely by the axle housing through the wheel bearings. The axle shafts can be removed and replaced without removing the wheel or disturbing the differential. Most military all-wheel drive trucks have full-floating axles.

f. Independent Suspension (Fig. 29-12). Live axles that are made to work with independent suspension usually are arranged so that the differential carrier is fixed to the chassis. The axles then are connected to it through constant velocity joints (para 28-6) so that the wheels are free to travel with the suspension.

g. Double Reduction (Fig. 29-13). Double-reduction rear axles often are used for heavy-duty trucks. The first gear reduction is obtained through a spiral-bevel pinion and gear as in the common single-reduction rear axles. The bevel pinion runs in brackets mounted on the differential carrier in two roller bearings. The bevel gear is mounted rigidly on a jackshaft with a spur pinion that runs on roller bearings at each end; these also are mounted in the differential carrier. The spur pinion drives a spur gear that is bolted to the differential case. The usual design is the full-floating axle configuration (para 29-10e).

h. Dual Ratio (Fig. 29-14). Dual-ratio, or two-speed, rear axles sometimes are used on trucks and passenger cars. They contain two different gear ratios that can be selected at will by the driver, usually by a manual-control lever. A dual-ratio rear axle serves the same purpose as the auxiliary transmission described previously. Like the latter, it doubles the number of gear ratios available for driving the vehicle under the various load and road conditions. This type of rear axle is shown in a cross-sectional view in figure 29-14. It is driven by the conventional spiral-bevel pinion and differential drive ring gear, but a planetary gear train is placed between the differential drive ring gear and differential case. The internal gear of the planetary train is bolted rigidly to the bevel drive gear. A ring on which the planetary gears are pivoted is bolted to the differential case. A

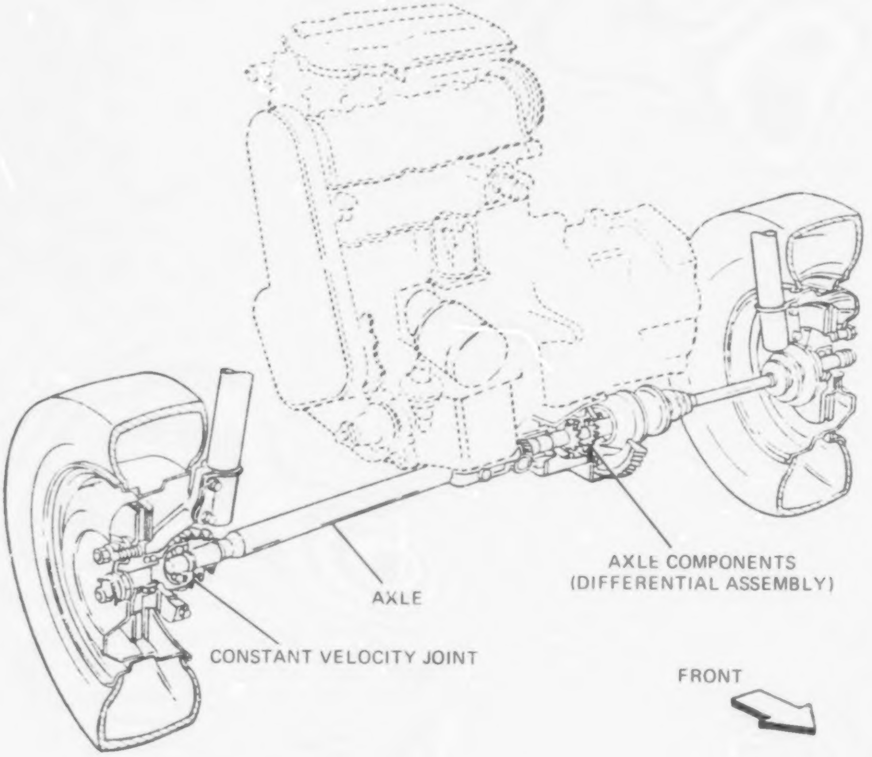


Figure 29-12. Independent Live Axle Suspension.

TA233788

541

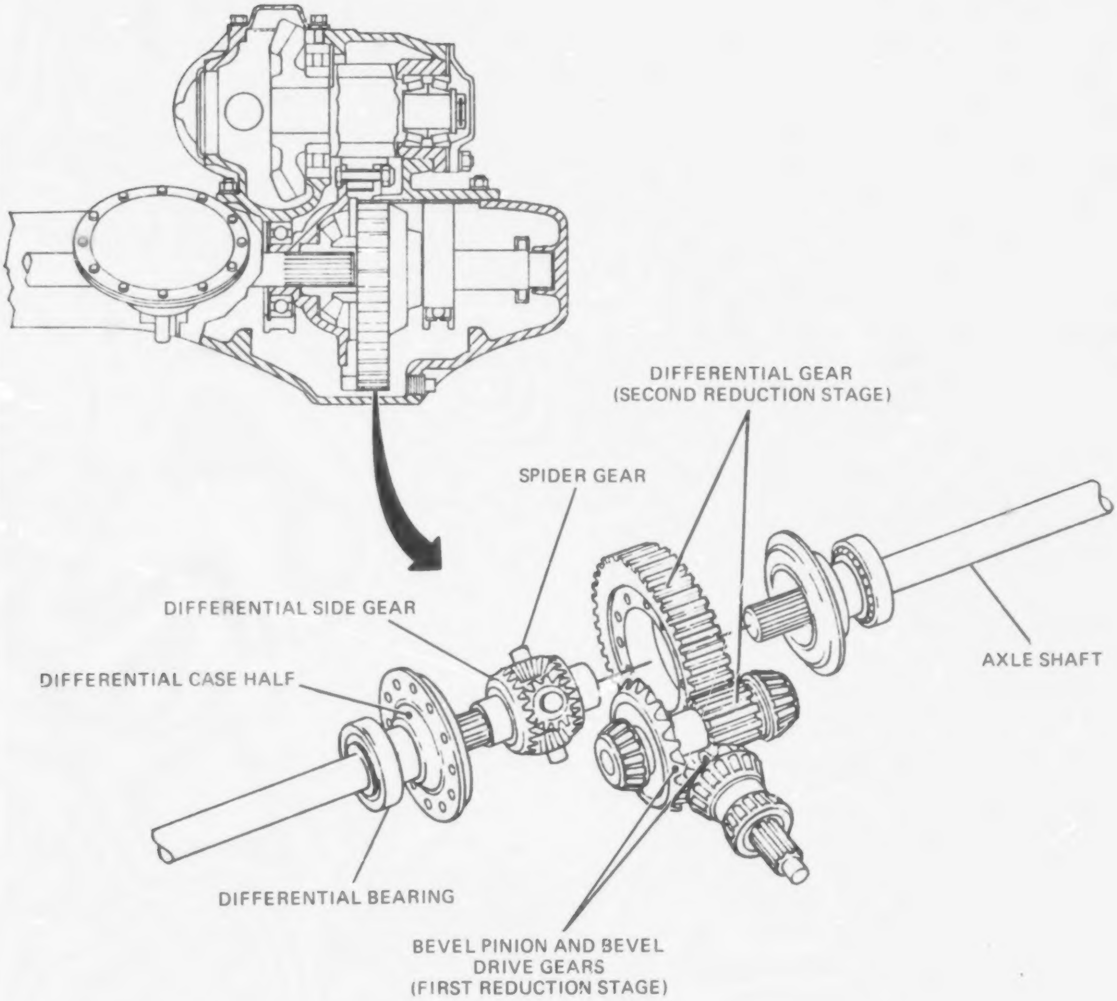

DIFFERENTIAL GEAR
(SECOND REDUCTION STAGE)
SPIDER GEAR
DIFFERENTIAL SIDE GEAR
AXLE SHAFT
DIFFERENTIAL CASE HALF
DIFFERENTIAL BEARING
BEVEL PINION AND BEVEL
DRIVE GEARS
(FIRST REDUCTION STAGE)

Figure 29-13. Double-Reduction Drive Axle.

member, consisting of the sun gear and a dog clutch, slides on one of the axle shafts and usually is controlled by a hand lever accessible to the driver. When this sliding part is in the high-ratio position, the sun gear meshes with internal teeth on the ring carrying the planetary gears and disengages the dog clutch from the left bearing adjusting ring, which is rigidly held in the differential carrier. In this position, the planetary gear train is locked together, there is no relative motion between the gears in the planetary train, and the differential case is driven directly by the differential drive ring gear the same as in the conventional single-ratio rear axle. In the low-ratio position, the sun gear is slid out of mesh with the ring carrying the planetary gears, and the dog clutch makes a rigid connection with the left bearing adjusting ring. Because the sun gear is integral with the dog clutch, it also is locked fast to the bearing adjusting ring and remains stationary. The internal gear rotates the planetary gears around the stationary sun gear and the differential case is driven by the ring on which the planetary gears are pivoted. This action produces the gear reduction, or low speed, of the axle.

i. Double Reduction, Dual Ratio (Fig. 29-15). Double-reduction, dual-ratio rear axles also are sometimes used in heavy-duty motor vehicles. Rear axles of this type combine the features of the double-reduction and dual-ratio axles in one unit. A spiral-bevel pinion drives a

TA233789

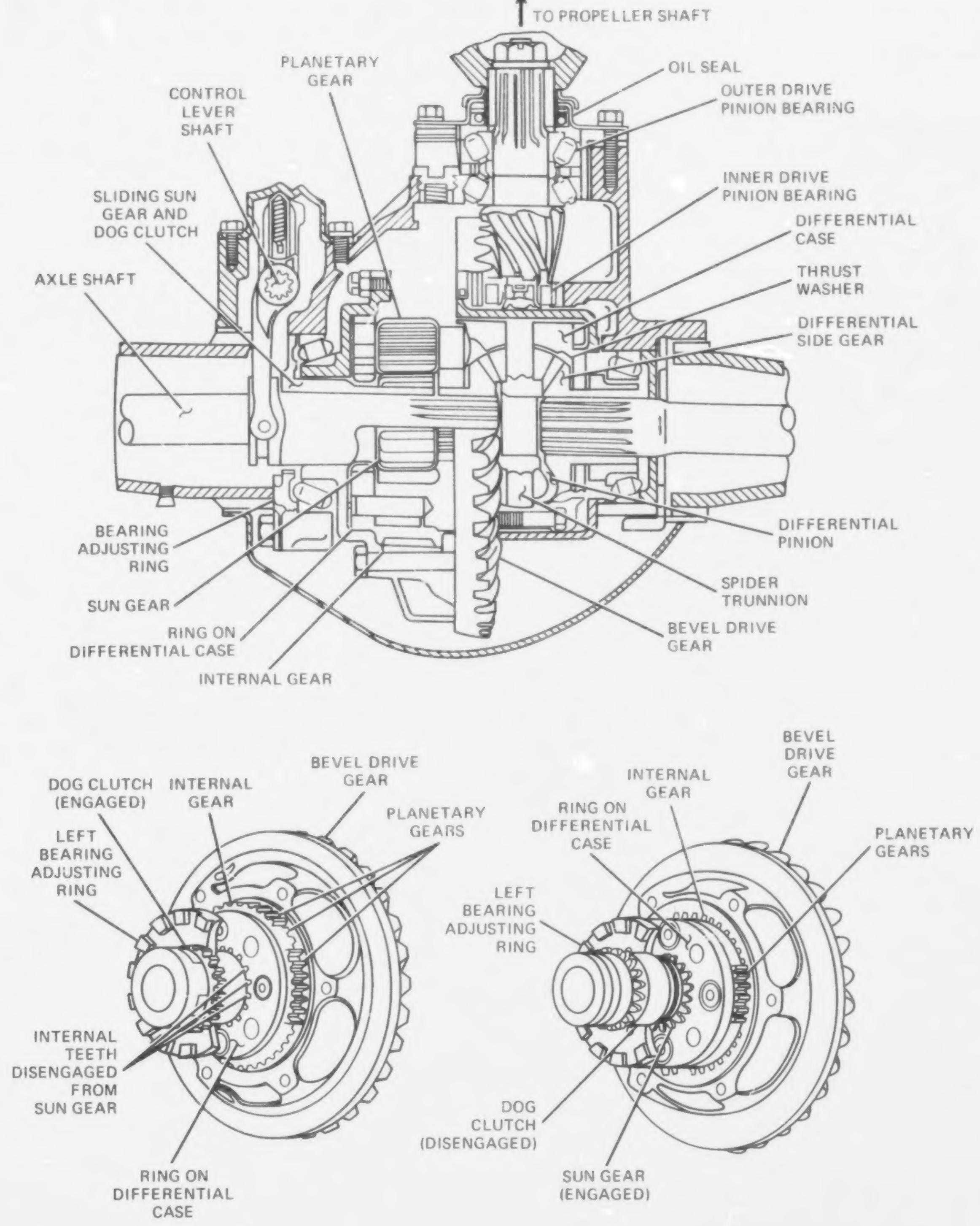

TO PROPELLER SHAFT
PLANETARY GEAR
CONTROL LEVER SHAFT
OIL SEAL
OUTER DRIVE PINION BEARING
SLIDING SUN GEAR AND DOG CLUTCH
INNER DRIVE PINION BEARING
DIFFERENTIAL CASE
AXLE SHAFT
THRUST WASHER
DIFFERENTIAL SIDE GEAR
DIFFERENTIAL PINION
BEARING ADJUSTING RING
SPIDER TRUNNION
SUN GEAR
BEVEL DRIVE GEAR
RING ON DIFFERENTIAL CASE
INTERNAL GEAR
BEVEL DRIVE GEAR
DOG CLUTCH (ENGAGED)
INTERNAL GEAR
PLANETARY GEARS
LEFT BEARING ADJUSTING RING
INTERNAL TEETH DISENGAGED FROM SUN GEAR
RING ON DIFFERENTIAL CASE
BEVEL DRIVE GEAR
INTERNAL GEAR
RING ON DIFFERENTIAL CASE
PLANETARY GEARS
LEFT BEARING ADJUSTING RING
DOG CLUTCH (DISENGAGED)
SUN GEAR (ENGAGED)

Figure 29-14. Dual-Ratio Drive Axle.

TA233790

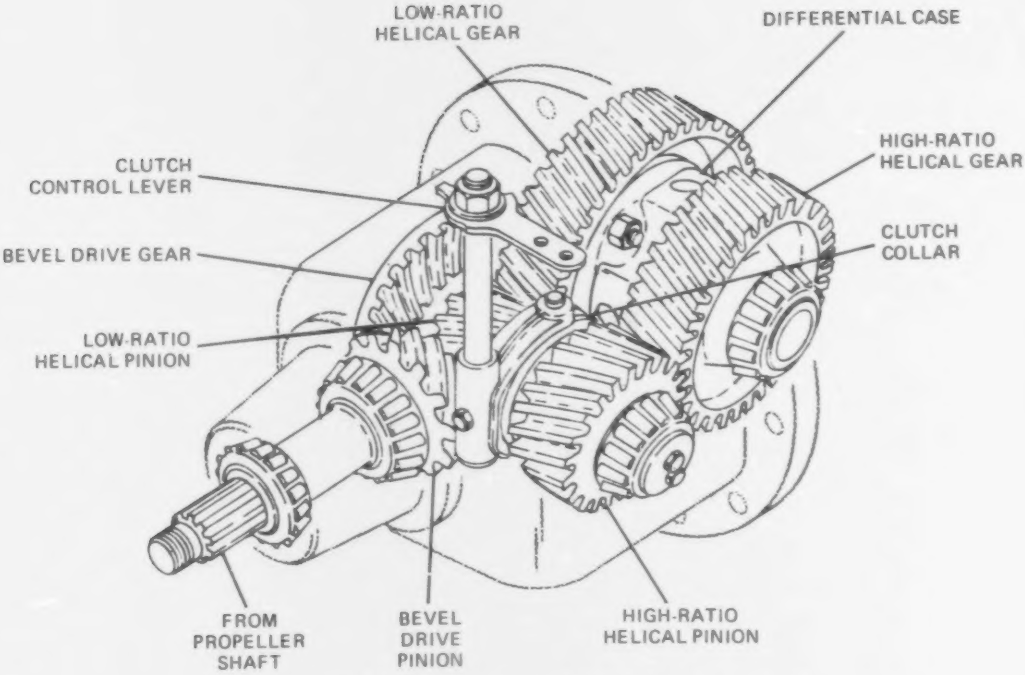


Figure 29-15. Double-Reduction Dual-Ratio Drive Axle.

jackshaft through a spiral-bevel drive gear. Two helical pinions of different sizes and a two-way dog clutch are mounted on the jackshaft. The two helical pinions are not fast to the jackshaft but rotate freely on it on bearings. They are in constant mesh with two helical gears of correspondingly different sizes, both mounted rigidly on the differential case. The sliding dog clutch is controlled by a hand lever and clutches either one of the helical pinions fast to the jackshaft. The drive is from the propeller shaft to the drive pinion, to the bevel drive gear, to the jackshaft, to the right helical pinion, to the right helical gear, to the differential case, to the differential pinions, to the differential side gears, to the axle shafts, and then to the wheels. When the dog clutch is in the high-speed position (moved to the left), the drive is the same, except that it is through the other pair of helical gears.

j. Interwheel Differential. One of the latest developments in front-wheel drives is dual wheels having an interwheel differential that makes them easily steerable. Each wheel is equipped with its own brake. Vertical steering knucle pivots are used. The differential is of the spur gear type, the pinions having a tooth form that gives it the same action as the high-traction differential described in paragraph 29-3. When dual front wheels are used in addition to dual rear wheels, a greater portion of the total load can be carried by the front axle. This makes a greater payload possible without increasing the overall length of the vehicle.

Interwheel differentials also can be used for front dead axles, live rear axles, tandem rear live axles, and trailer dead axles to provide for the difference in distance traveled by each of the pair of dual wheels in rounding curves, and for the different rolling radius of each of the dual wheels caused by the crown of the road or ruts. It is thought that a great saving in tire wear results because of the elimination of the slippage that occurs when dual wheels are bolted together rigidly.

k. Power Divider (Fig. 29-16).

(1) The forward rear axle is of the full-floating, double-reduction type having a spiral-bevel pinion and gear for the first reduction, and a spur pinion and gear for the second reduction. The spiral-bevel pinion is driven through a power divider, which also drives the rearward rear axle through a shaft that passes through the pinion of

TA233791

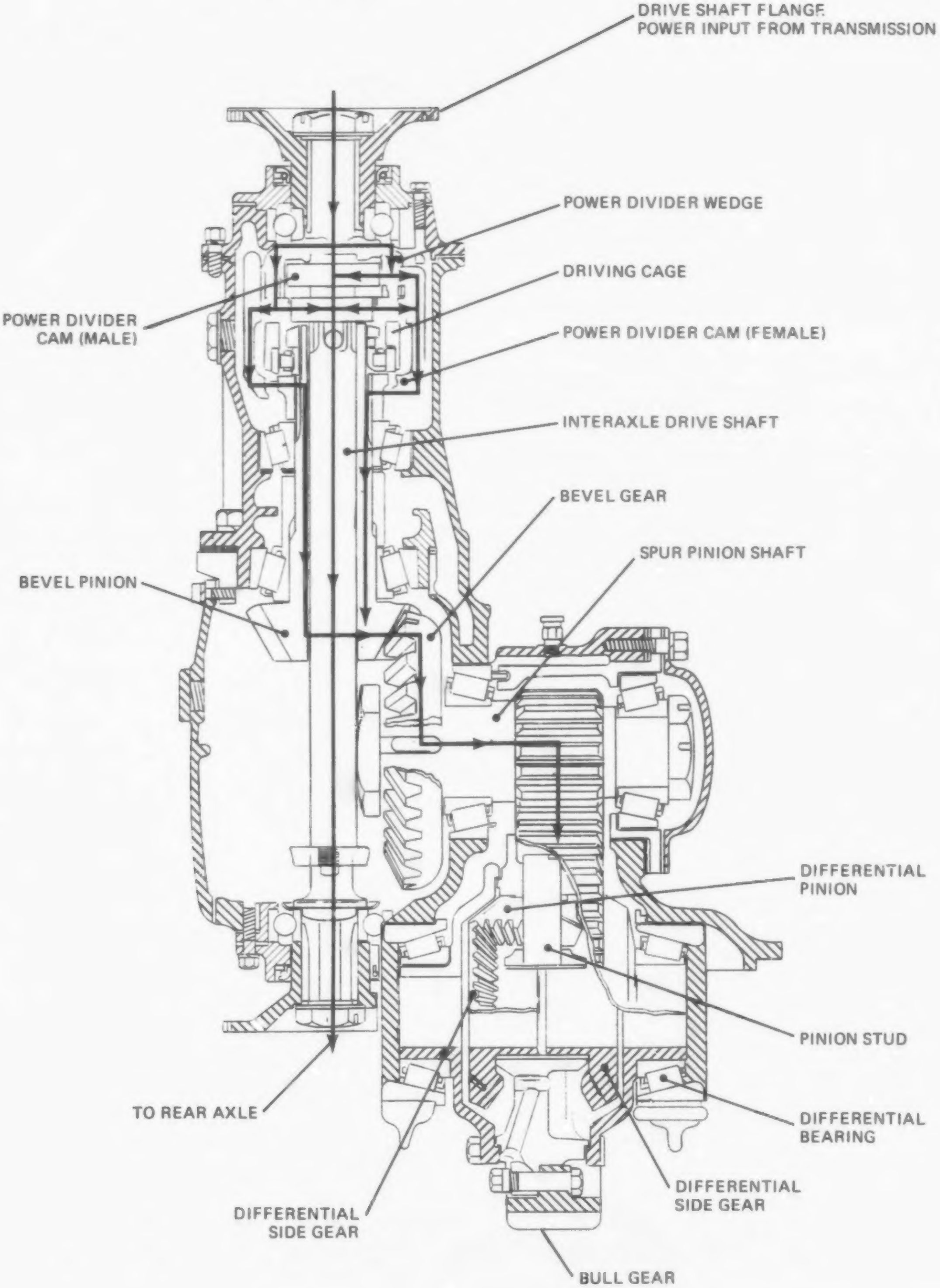

DRIVE SHAFT FLANGE
POWER INPUT FROM TRANSMISSION
POWER DIVIDER WEDGE
DRIVING CAGE
POWER DIVIDER CAM (MALE)
POWER DIVIDER CAM (FEMALE)
INTERAXLE DRIVE SHAFT
BEVEL GEAR
SPUR PINION SHAFT
BEVEL PINION
DIFFERENTIAL PINION
PINION STUD
TO REAR AXLE
DIFFERENTIAL BEARING
DIFFERENTIAL SIDE GEAR
DIFFERENTIAL SIDE GEAR
BULL GEAR

Figure 29-16. Gear Carrier with Power Divider.

TA233792

the forward rear axle, and is attached to the forward end of the interaxle drive shaft.

(2) The power divider is attached to the forward end of the gear carrier, which is mounted on the upper side of the axle housing. Both forward and rear axles are driven from the forward drive flange through the power divider by means of a driving cage carrying two parallel rows of radial wedges or plungers engaging at their outer ends with internal (female) cams on a cage that drives the bevel pinion of the forward rear axle. At their inner ends, the plungers engage with external (male) cams on the interaxle drive shaft, which drives the bevel pinion of the rear axle. Due to the wedging action between the cams and the plungers, they rotate together with no relative movement, unless running condition require a differential action.

(3) Whenever either the forward or the rear pair of wheels tends to run ahead of the other pair, due to slippage or uneven road surfaces, there is a relative movement of the external and internal cams, which is permitted by the sliding of the radial plungers in the driving cage. This restricted movement provides a differential action that divides the driving effort to the two pairs of wheels to provide the maximum tractive effort. The wheel spindles are pressed into the axle housing, and the brake assemblies are carried by integral flanges. The underslung springs, which tie the two rear axle housings together in parallel relation, are attached by means of rubber shock insulators set in sockets on the bottom of the housing, and retained by caps.

(4) A ball-joint torque rod, between the top of the gear carrier housing and a chassis frame crossmember, takes the torque conveyed to the axle assembly by the driving and braking.

l. Front Wheel (Steerable) Live Axle.

(1) In four- or six-wheel drives, the front wheels are driven through a driving axle assembly very similar to a rear axle. It may be of the single- or double-reduction type. Figure 29-17 shows a usual arrangement of transfer assembly, propeller shafts, universal joints, driving axles, and springs for a four- or six-wheel drive vehicle. Front-wheel drives ordinarily are Hotchkiss drives with the front springs pivoted at the rear and shackled at the front. Axles are of the full-floating type. As in the case of rear live axles, the axle housings usually are built up, but they may be pressed steel for light vehicles and single-piece castings for heavy-duty vehicles. The split-type housing frequently is used. The principal difference between front live axles and rear axles is that in front-wheel drives, provision must be made for steering. In rear driving axles, the axle shafts are connected directly to the wheels. Because the front wheels must turn on the steering knuckle pivots, they usually are driven by the axle shafts through universal joints (para 28-7) concentric with the steering knuckle pivots. Figure 29-17 shows the housings of the steering knuckle pivots and constant-velocity universal joints, as well as the tie rod, brakedrums, hub flanges, and wheel mounting studs for a typical front live axle assembly.

(2) A type of front-wheel drive that drives the front wheels through gearing and permits them to steer without the use of a universal joint is shown in figure 29-18. It has been used to a very limited extent. A spiral-bevel pinion keyed to the end of the axle shaft drives the lower half of a double bevel gear on the lower end of the steering knuckle pivot. The top half of the double gear meshes with a fourth gear that is integral with the wheel hub. The gear and hub turn on the steering knuckle. When the wheels are cramped, the bevel gear on the wheel hub rotates around the bevel gear on the steering knuckle pivot.

(3) Constant-velocity universal joints, used with front-wheel drives to avoid strain on the steering mechanism, are discussed in chapter 28.

m. Four Rear-Wheel Drives.

(1) Motor vehicles that carry extremely heavy loads often are equipped with four rear wheels in order to increase traction and to avoid excessive weight on the rear tires; that is, the weight of the load is divided among twice as many tires as when only one rear axle is used. Dual wheels generally are used with this arrangement; therefore, the weight of the rear of the vehicle and load is divided among eight tires instead of four.

(2) Different spring suspensions are used, but the bogie is most general. A bogie consists of two axles joined by a trunnion axle. The trunnion

546

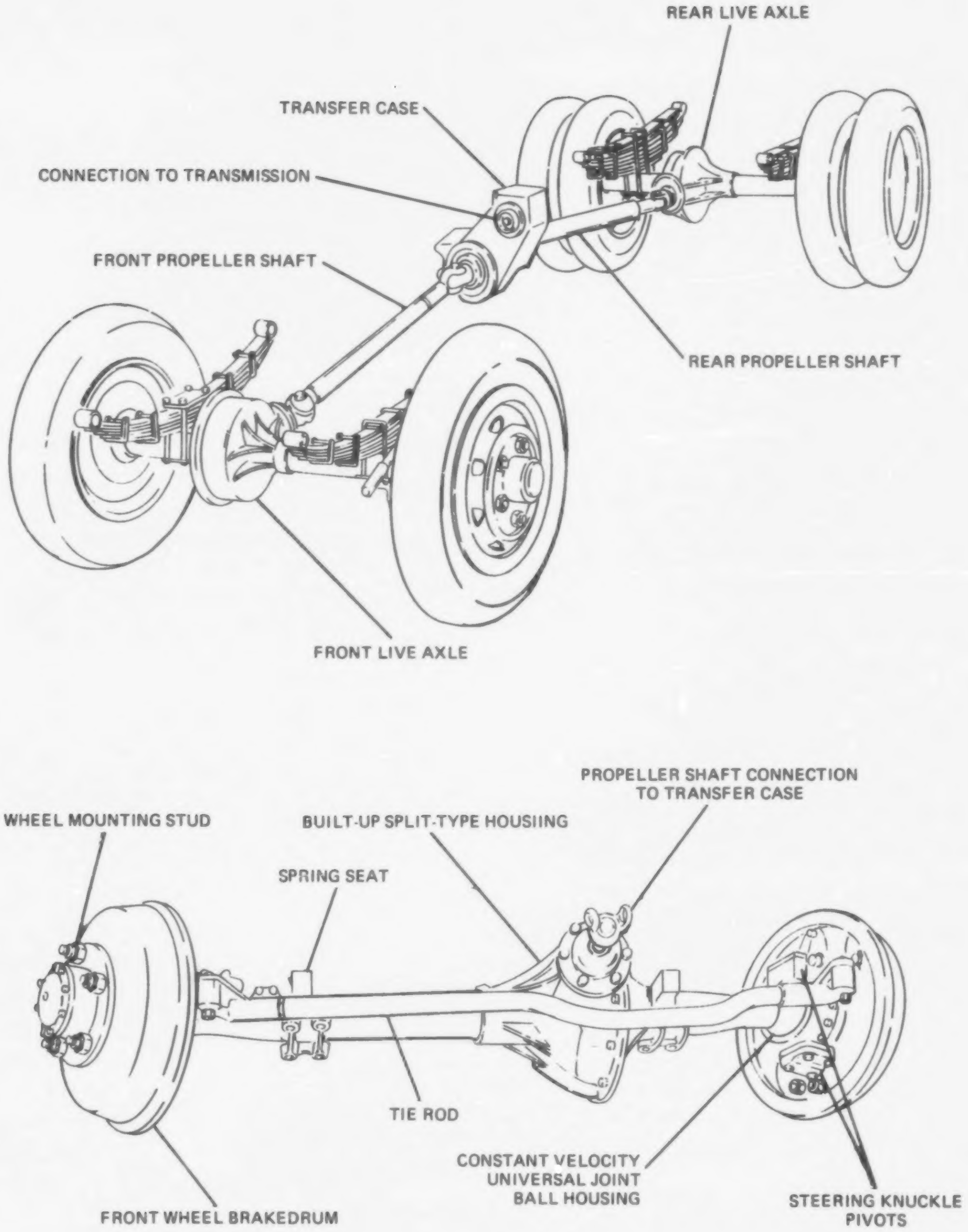

REAR LIVE AXLE
TRANSFER CASE
CONNECTION TO TRANSMISSION
FRONT PROPELLER SHAFT
REAR PROPELLER SHAFT
FRONT LIVE AXLE
PROPELLER SHAFT CONNECTION TO TRANSFER CASE
WHEEL MOUNTING STUD
BUILT-UP SPLIT-TYPE HOUSIING
SPRING SEAT
TIE ROD
CONSTANT VELOCITY UNIVERSAL JOINT BALL HOUSING
STEERING KNUCKLE PIVOTS
FRONT WHEEL BRAKEDRUM

Figure 29-17. Front Live Axle Assembly and Four-Wheel Drive Installation. TA233793

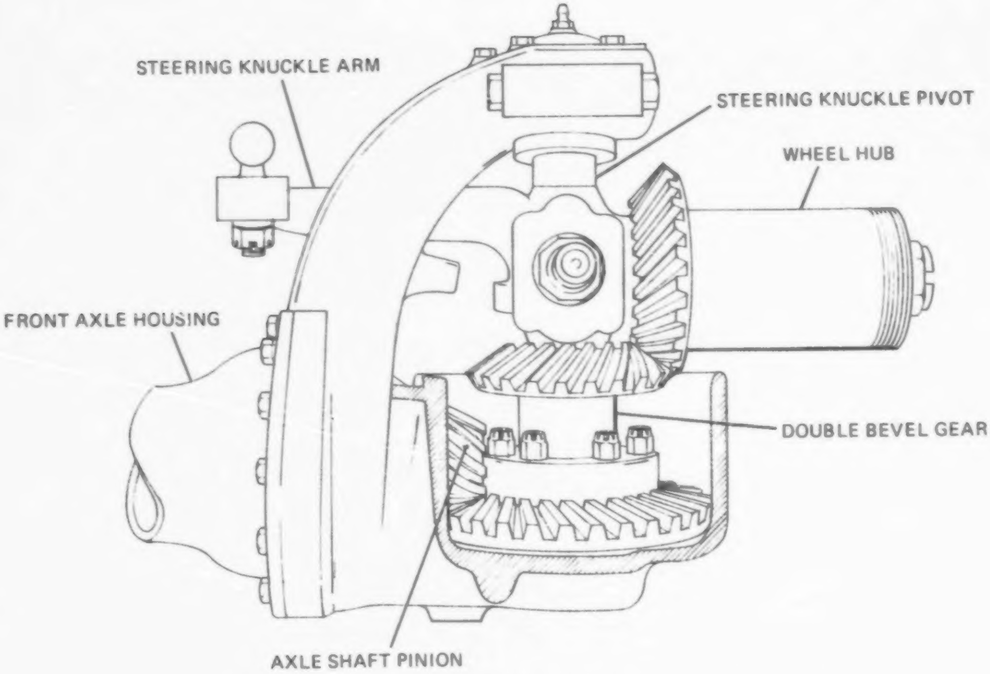


Figure 29-18. Helical Gear Drive for Steerable Wheels.

axle passes directly beneath the rear cross-member of the frame.

(3) Vehicles having this equipment may be either four- or six-wheel drive. Sometimes the dual rear axles are driven by independent propeller shafts (fig. 29-19) from a transfer assembly. In this case, the propeller shaft to the rearmost rear axle is divided into three parts, the short middle part passing through bearings mounted on the forward rear axle. The transfer assembly may contain an interaxle differential, but usually does not.

(4) Another arrangement is the tandem drive (fig. 29-20), employing double-reduction axles. A single propeller shaft from the transmission transfer assembly is connected to the forward rear-axle drive pinion through a shaft, and another short interaxle propeller shaft connects the drive pinion shaft of the forward rear axle with the drive pinion shaft of the rearward rear axle. Ordinarily, no interaxle differential is used, but one that is built into the forward rear axle is used sometimes. With the tandem drive, no transfer assembly is required if the vehicle drives on the four rear wheels only. If the front wheels also are driven, a transfer assembly is required.

TA233794

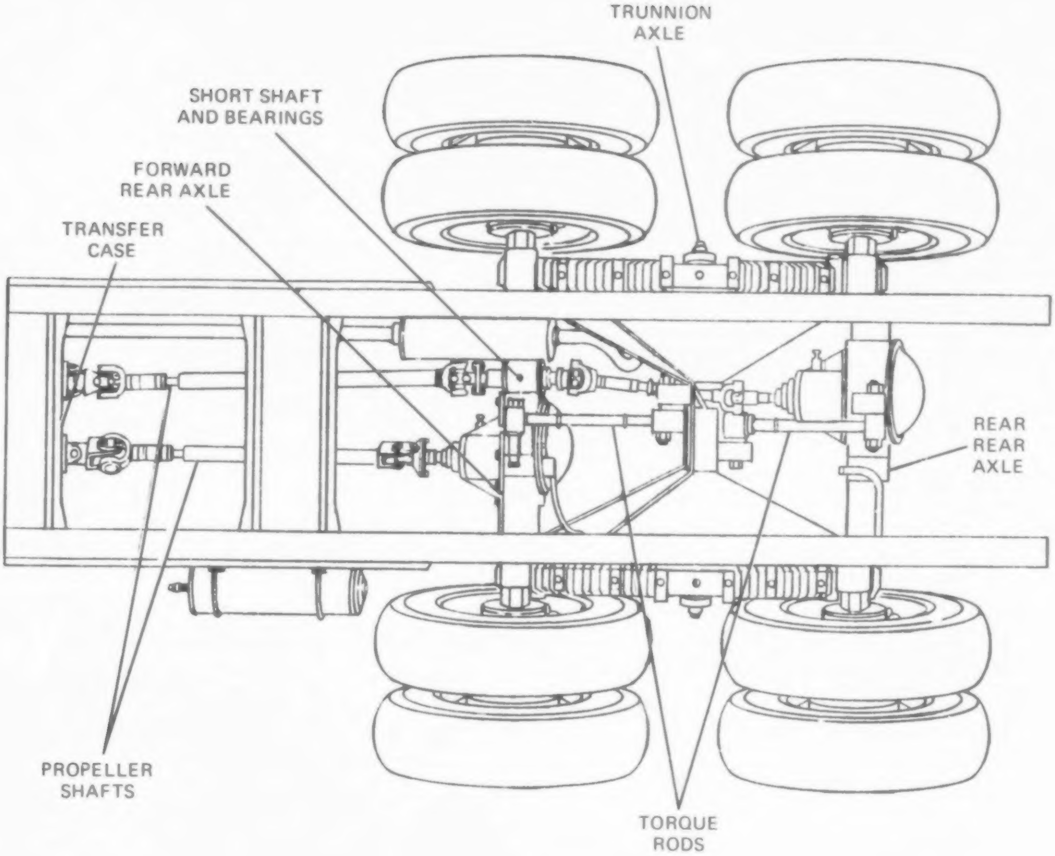

TRUNNION AXLE
SHORT SHAFT AND BEARINGS
FORWARD REAR AXLE
TRANSFER CASE
REAR REAR AXLE
PROPELLER SHAFTS
TORQUE RODS

Figure 29-19. Tandem Axles with Individual Propeller Shafts.

TA233795

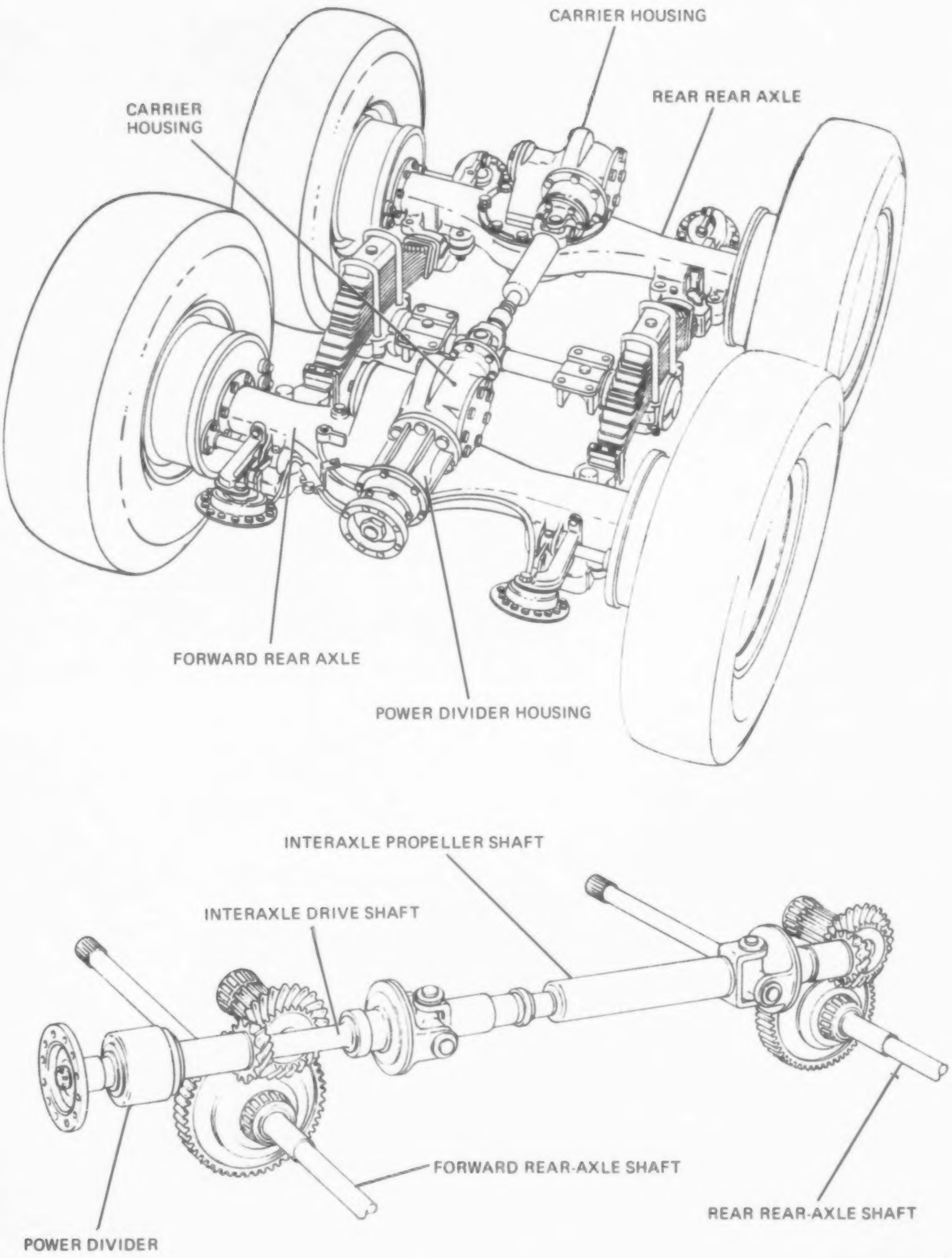

CARRIER HOUSING
REAR REAR AXLE
CARRIER HOUSING
FORWARD REAR AXLE
POWER DIVIDER HOUSING
INTERAXLE PROPELLER SHAFT
INTERAXLE DRIVE SHAFT
FORWARD REAR-AXLE SHAFT
REAR REAR-AXLE SHAFT
POWER DIVIDER

Figure 29-20. Tandem Axles with Power Divider.

TA233796

Section IV. CONTROLLED DIFFERENTIAL

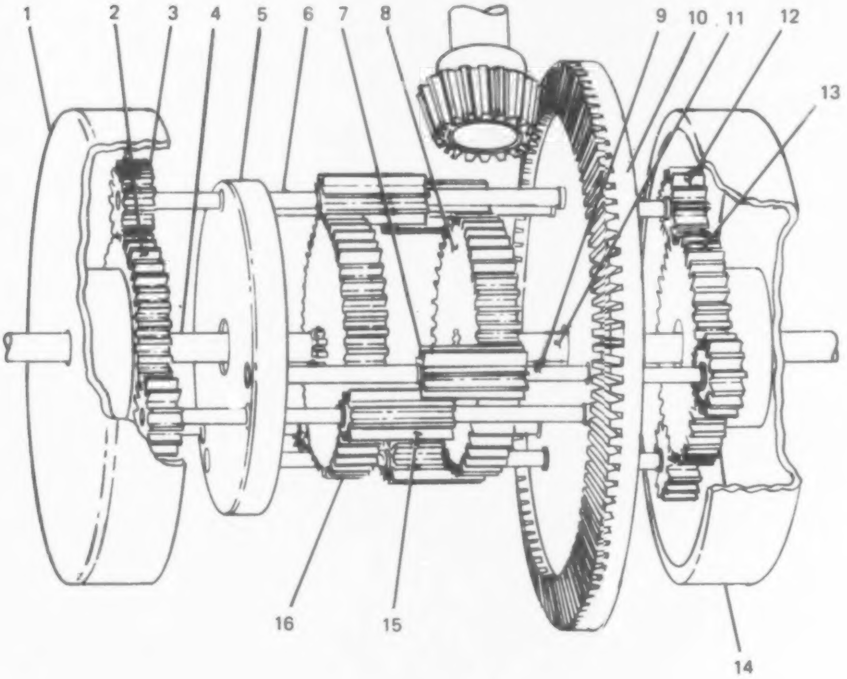
29-11. Purpose. The controlled differential is used in tracked vehicles for:

(a) Transmitting engine torque to the tracks.

(b) Steering of the vehicle through the controlled use of side-to-side braking.

29-12. Construction (Fig. 29-21 and 29-22). The controlled differential is, in reality, two different assemblies having left and right units joined by the differential carrier. Each side consists of a brakedrum, a sun gear, three external pinions, three internal pinions, and one compensating gear.

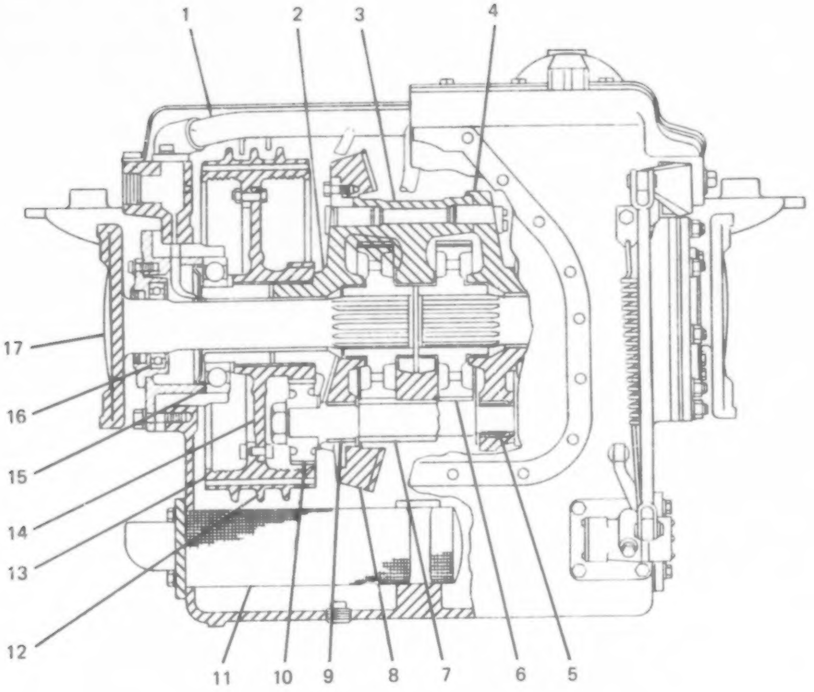
29-13. Operation (Fig. 29-21 and 29-22). When the vehicle is moving straight ahead, the entire differential assembly turns as a unit and transmits equal power and speed to each track through the final drive. When the left brake band is applied to the brakedrum, the left compensating gear is retarded and rotates slower than the differential carrier, while the right compensating gear is speeded up and rotates faster than the differential carrier. As each compensating shaft is splined to each compensating gear, the final analysis will result in the left track revolving slower than the right track, causing the vehicle to turn to the left. Exactly the reverse procedure takes place if the right brake is applied.



1. STEERING BRAKE RIM
2. STEERING BRAKE RIM FLANGE GEAR
3. DIFFERENTIAL RH EXTERNAL PINION
4. FINAL DRIVE SHAFT
5. COMPENSATING GEAR CASE COVER
6. PINION SHAFT
7. LH INTERNAL PINION
8. LH COMPENSATING GEAR
9. PINION SHAFT
10. FINAL DRIVE SHAFT
11. DRIVE GEAR
12. DIFFERENTIAL LH EXTERNAL PINION
13. STEERING BRAKE RIM FLANGE GEAR
14. STEERING BRAKE RIM
15. RH INTERNAL PINION
16. RH COMPENSATING GEAR

Figure 29-21. Controlled Differential.

TA233797


1
2
3
4
17
16
15
14
13
12
11
10
9
8
7
6
5

1. OIL MANIFOLD
2. RIGHT COMPENSATING CASE COVER
3. COMPENSATING CASE
4. LEFT COMPENSATING CASE COVER
5. SMALL PINION BEARING
6. DIFFERENTIAL FINAL DRIVE SHAFT GEAR
7. INTERNAL PINION
8. RING GEAR
9. LARGE PINION BEARING
10. EXTERNAL GEAR
11. OIL SCREEN
12. STEERING BRAKESHOE
13. STEERING BRAKEDRUM
14. STEERING BRAKEDRUM FLANGE
15. COMPENSATING CASE COVER BEARING
16. FINAL DRIVE SHAFT BEARING
17. DIFFERENTIAL FINAL DRIVE SHAFT

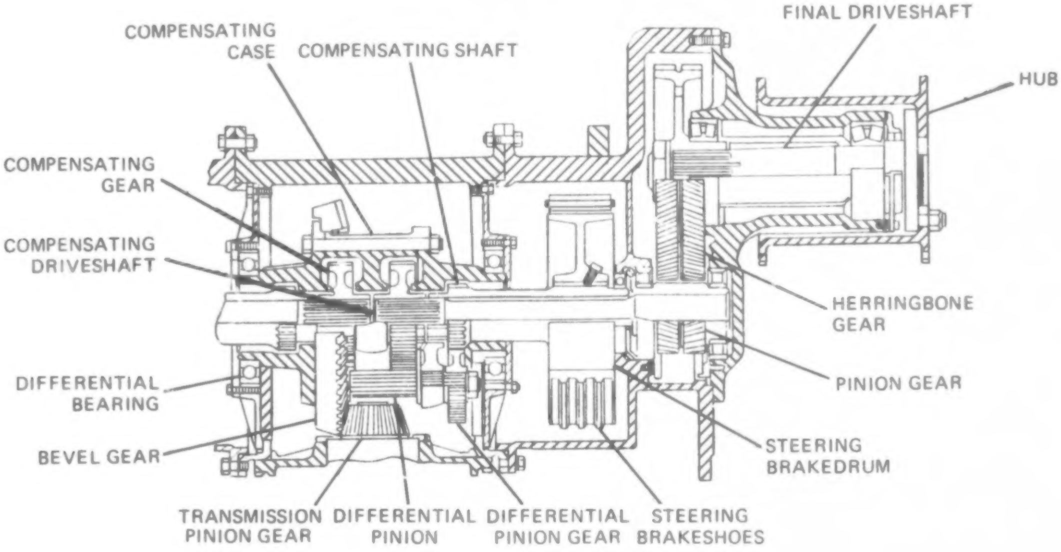

COMPENSATING CASE
COMPENSATING SHAFT
FINAL DRIVESHAFT
HUB
COMPENSATING GEAR
COMPENSATING DRIVESHAFT
HERRINGBONE GEAR
PINION GEAR
DIFFERENTIAL BEARING
STEERING BRAKEDRUM
BEVEL GEAR
TRANSMISSION PINION GEAR
DIFFERENTIAL PINION
DIFFERENTIAL PINION GEAR
STEERING BRAKESHOES

Figure 29-22. Controlled Differential with Final Drive.

TA233798

552

Section V. WHEEL VEHICLE PERFORMANCE

29-14. General. There are many different aspects of vehicle performance. Miles per gallon of fuel, miles per hour in first, second, or other gear ratio, and the amount of weight a vehicle can carry are all commonly considered factors. Other factors of equal importance include tractive factor, grade ability, and drawbar pull. These three factors refer to less-known performance aspects that should be considered further.

29-15. Performance Factors.

a. *Tractive Factor.*

(1) Tractive factor refers to the pushing effort the wheels can make against the ground as a result of the application of torque to them through the power train from the engine. Actually, the tractive factor is given in pounds-of-push for each pound of vehicle weight. Tractive factor can be determined by the following formula:

$$\text{Tractive factor} = \frac{\text{ET} \times \text{R} \times 0.85}{\text{GW} \times \text{TLR}}$$

where ET = Engine torque from dynamometer tests, with at least distributor and water pump operating (ft lb).

R = Gear ratio at reduction under consideration.

0.85 = Efficiency of power transmission (arbitrarily chosen as an average value).

GW = Gross vehicle weight (lb).

TLR = Tire loaded radius (ft).

(2) Figure the tractive factor of a 1/4-ton, 4 x 4 utility truck. This can be determined in any gear, and with the truck loaded or unloaded. The tractive factor will increase with increased gear ratio, and will decrease as the vehicle is loaded. Generally, the tractive factor is figured with maximum payload because this gives an indication of the vehicle performance under the most adverse conditions. However, calculate the tractive factor of the 1/4-ton, 4 x 4 truck at maximum gear reduction and unloaded. Unloaded, the vehicle weighs 2,625 pounds. The engine torque is 79 ft lb. The gear reduction in the transmission in low gear is 2.798:1; in the transfer in low range, 2.43:1; and in the differentials, 5.38:1. Total gear reduction is 36.7:1, in low range, low gear. Tire radius is 1.25 feet, unloaded; and slightly less, loaded. However, use the figure 1.25 feet for ease of figuring. Substituting all this data in the formula gives:

$$\text{Tractive factor} = \frac{79 \times 36.7 \times 0.85}{2.625 \times 1.25} = 0.75.$$

(3) This figure means the tires can exert a push against the ground of 0.75 pound for every pound of vehicle weight. If the tires do not slip, the vehicle can be pushed forward 0.75 pound for every pound of vehicle weight.

b. *Grade Ability.*

(1) Grade ability refers to how steep a grade the vehicle can climb. Grade, itself, is referred to in percent: a 10-percent grade, or a 26-percent grade, for example. A 1-percent grade rises 1 foot in every 100 feet. A 26-percent grade rises 26 feet in every 100 feet. If the tractive factor is known, the grade ability can be easily figured by use of the formula:

$$\text{Grade ability} = (\text{Tractive factor} - 0.015) \times 100$$

where 0.015 equals rolling resistance per pound of vehicle weight (arbitrarily chosen as an average value).

(2) Figure the maximum grade ability of the 1/4-ton, 4 x 4 truck for which calculated the tractive factor (maximum) was 0.75. Substituting in the formula would give:

$$\text{Grade ability} = (0.75 - 0.015) \times 100 = 0.735 \text{ or } 73.5 \text{ percent.}$$

(3) The truck, unloaded and in low range, low gear, could go up a 73.5-percent grade; that is a grade that rises 73.5 feet every 100 feet. It can be seen that the grade ability of a vehicle will vary with the load and the gear ratio. It will decrease as

the vehicle is loaded and increase as gear ratio is increased.

c. Drawbar Pull.

(1) The drawbar pull is an indication of how much the vehicle can pull on a trailer attached to it. Drawbar pull can be calculated if the tractive factor and weight on powered wheels are known by use of the following formula:

Drawbar pull = Tractive factor x
weight on powered wheels.

(2) In the vehicle under discussion (1/4-ton, 4 x 4 truck), it was determined that the maximum tractive factor was 0.75 with a vehicle weight of 2,625 pounds. Because all wheels are powered, multiplying these two figures together gives the drawbar pull, or 0.75 x 2,625 pounds equals 1,970 pounds. That is, the vehicle can produce a maximum drawbar pull of 1,970 pounds (provided, of course, that no wheels slip). Note that, if the vehicle itself is loaded, it will tend to increase the drawbar pull; however, at the same time, loading the vehicle reduces the tractive factor. If, for example, a 1,000-pound load were added to the vehicle, giving a gross weight of 3,625 pounds, the tractive factor would drop to approximately 0.55. This, times 3,625 pounds, gives a maximum drawbar pull of approximately 1,970 pounds. For a vehicle having all-wheel drive, the drawbar pull is a constant, regardless of the weight carried by the vehicle. Note that the term maximum has been used here; this means that the vehicle could supply this amount of pull. However, in actual performance, the vehicle is not required to supply this amount of drawbar pull. The applicable technical manual for any vehicle specifies the maximum trailer load to be attached. The 1/4-ton, 4 x 4 truck under analysis, for example, has a maximum limit of 2,000 pounds trailer load on the highway (1,500 pounds cross country).

554

PART FIVE

CHASSIS COMPONENTS

CHAPTER 30

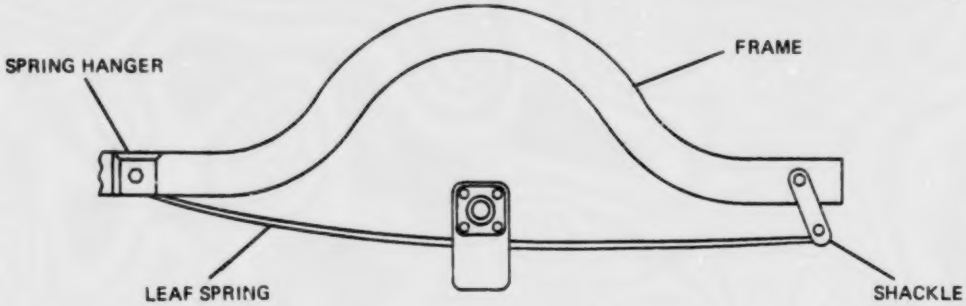
SUSPENSION SYSTEMS IN WHEELED VEHICLES

Section I. OVERVIEW

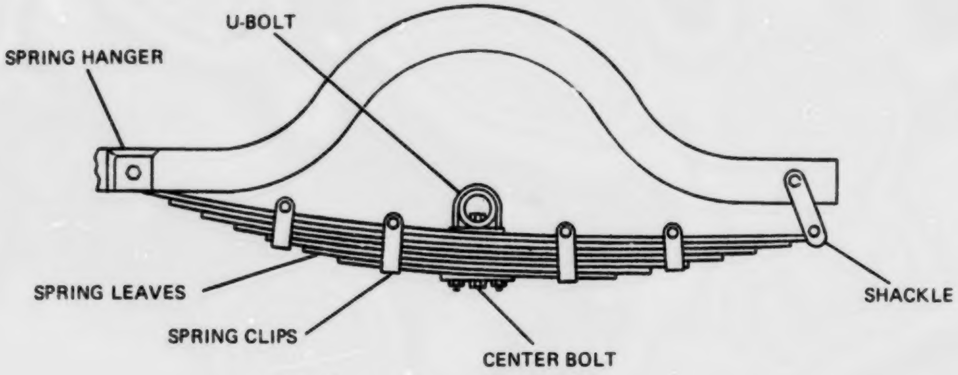
30-1. Purpose. The suspension system's main purpose is to support the weight of the vehicle. Military vehicles, which are often very heavy and must be able to cross all types of terrain, depend heavily on their suspension systems. In wheeled vehicles, the suspension must not only be effective over a wide range of speed and land conditions, but also must allow for steering geometry and changes in terrain. In tracked vehicles, such as a tank, the suspension system must support the vehicle so that the immense weight will not sink down, even in soft ground. The suspension system also must absorb bumps and jolts.

30-2. Spring Configurations.

a. Leaf Springs. Leaf springs usually are semielliptical in shape and are made of high quality alloy steel. There are two types of leaf springs. The single leaf spring, or monoleaf (A, fig. 30-1), is a single layer spring that is thick in the center and tapers down at each end.



A. SINGLE LEAF SPRING



B. MULTILEAF SPRING

Figure 30-1. Leaf Springs.

TA233799

Single leaf springs generally are used on lighter suspension systems that do not have to carry great loads. A multileaf spring (B, fig. 30-1) is made up of a single leaf with additional leaves attached to it using spring clamps. The additional leaves make the spring stiffer, allowing it to carry greater loads. As a multileaf spring operates, there is a friction generated between the leaves, causing it to have a dampening quality. These types of springs may not require the use of a shock absorber in some applications. The multileaf spring uses a frictional material laminated between the leaves to reduce wear and eliminate any squeaks that might develop. To keep the leaves equally spaced lengthwise, the multileaf spring uses a center bolt. The center bolt rigidly holds the leaves together in the middle of the spring, preventing the leaves from moving off center. Leaf springs are attached to the vehicle using a bracket usually mounted rigidly to the frame in the front, and a shackle in the rear, which allows the spring to expand and contract without binding as it moves through its arc.

b. Coil Springs. These springs usually are made of round spring steel wound into a coil (fig. 30-2). Because of their simplicity, they are less costly to manufacture and also have the widest application. Spring stiffness is changed on coil springs by toughening them. Coil springs, like torsion bars and volute (or spiral-shaped) springs, are frictionless and require the use of a shock absorber to dampen vibrations. Their cylindrical shape requires less space to operate in. Pads sometimes are used between the spring and chassis to eliminate transferring vibrations to the body. Coil springs are not able to absorb any torque when employed in the suspension system. Therefore, control arms and stabilizers are required to maintain the proper geometry between the body and suspension system (fig. 30-2).

c. Torsion Bars. The torsion bar consists of a steel rod usually made of spring steel. It is treated with heat or pressure to make it elastic, so it will retain its original shape after being twisted. Torsion bars, like coil springs, are frictionless and require the use of shock absorbers. The torsion bar is serrated on each end and is attached to the torsion bar anchor at one end and to the suspension system at the other (fig. 30-3). Torsion bars are marked to indicate proper installation by an arrow stamped into the metal. It is essential that they be installed properly because they are designed to take stress in one direction only. The elasticity of the rod is utilized and as long as the elastic limit is not exceeded, the torque resistance will return the suspension to its normal position in the same manner as a spring arrangement.

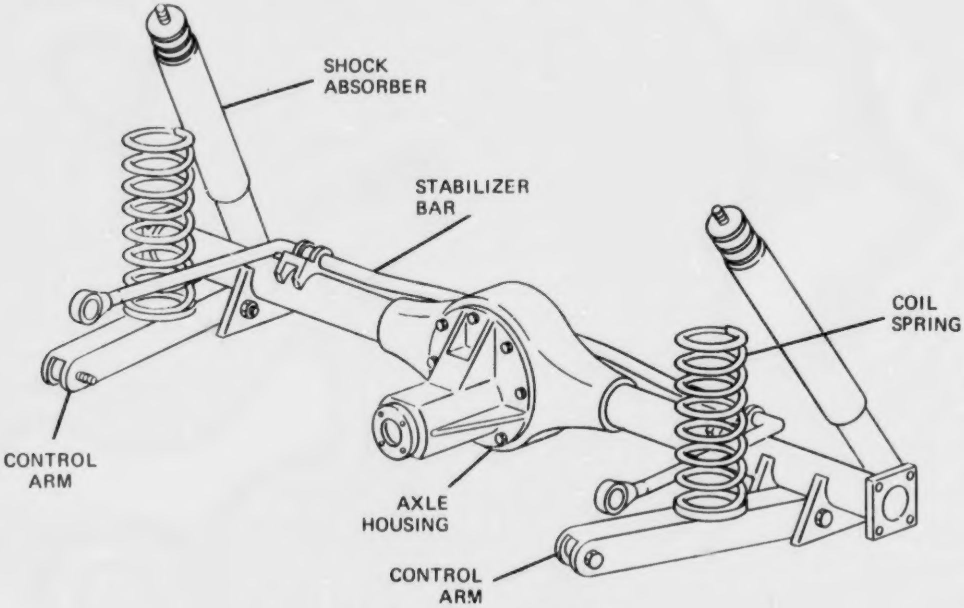


Figure 30-2. Coil Springs.

TA233800

S.56

BEST COPY AVAILABLE

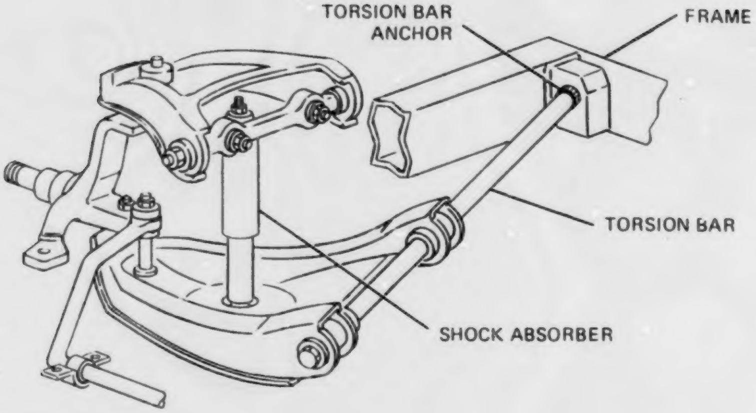


Figure 30-3. Torsion Bar.

Section II. SOLID AXLE SUSPENSION SYSTEMS

30-3. Purpose. The axle of the suspension is a cross support on which the wheels turn. Axles that provide only support for the vehicle weight are called dead axles. Those that also incorporate means for driving the wheel are called live axles. The term live axle applies to the entire axle assembly, which consists of the housing that contains the drive gears, differential, and power transmitting shafts. Until recently, wheeled military vehicles have employed the solid axle suspension, both front and rear, almost exclusively. This is because of the basic ruggedness, low manufacturing cost, and wide use on heavy commercial vehicles of the solid axle suspension.

30-4. Live Axle Suspension.

a. The Hotchkiss drive is the conventional front and rear live axle suspension that once was used exclusively in American military vehicles. In this drive, a propeller shaft (drive shaft) is employed with two universal joints and a slip joint, as shown in figure 30-4. The torque reaction, drive thrust, and alinement of the axle housings are resisted by the suspension springs.

The suspension springs are pivoted on brackets at their forward ends and shackled to the frame at their rear ends. The rear spring brackets are the point of application of the driving thrust to the frame. Because the suspension springs must resist the torque reaction of the drive, stiffer springs are required than are used with some of the other live axle suspensions. In addition, because the springs must transmit the driving thrust, they must be fairly flat. Because of these torque and force transmission requirements, the Hotchkiss drive has been criticized as providing

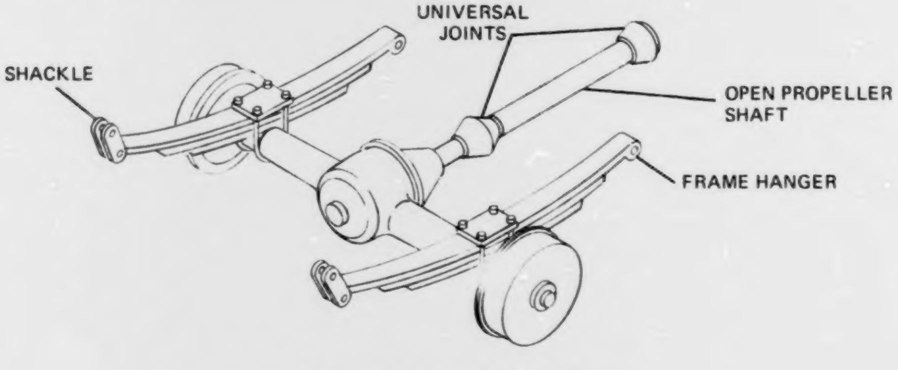


Figure 30-4. Hotchkiss Drive.

TA233801

poor riding qualities, thereby limiting vehicle mobility. However, this drive system is in extensive use because of simplicity, low cost, and ruggedness.

An advantage of the Hotchkiss drive is that the flexible connection between axle and frame throws less strain on the driving mechanism than do other types. When sudden loads are applied, as in suddenly engaging the clutch, the axle housing can rock around the drive shaft slightly, which cushions the shock transmitted through the driving mechanism and reduces the load between the teeth of the final driving mechanism.

b. The torque tube drive, while not common on heavy military vehicles, is used on a limited number of passenger and light commercial vehicles. In this type of drive, the propeller shaft (drive shaft) is housed in a steel tube called the torque tube (fig. 30-5). The rear end of the torque tube is bolted rigidly to the rear axle housing by means of a flange. Its front end is connected to the transmission or a frame crossmember by means of a ball-and-socket joint. One universal joint is used in the propeller shaft and is located at the ball-and-socket joint of the torque tube. A slip joint is placed in the propeller shaft to take up end play arising when the driven axle moves up and down. A center bearing generally is used to support the drive shaft in the torque tube.

Two suspension system radius rods are used to connect the outboard ends of the axle housing with the transmission end of the torque tube. This will keep the axle housing alined at right angles to the torque tube. The suspension springs are shackled at both ends.

In a torque tube drive, both the torque reaction and the driving thrust are resisted by the torque tube. Because the suspension springs do not resist the torque reaction and drive thrust, they can be made more flexible and give better riding qualities than a Hotchkiss drive.

In a torque tube drive, the driving thrust is applied to the frame at the engine mounting or at a frame crossmember. In a torque rod or Hotchkiss drive, the force is applied at the suspension springs. The torque tube drive seldom is used in contemporary designs.

c. The torque arm drive rarely is used. It consists of a solid or tubular arm, rigidly connected to the driving axle housing at its rear end and to a frame crossmember, through a ball-and-socket joint or spring bracket, at its front end (fig. 30-6). An open propeller shaft is used on a torque arm drive. The torque arm drive is similar to the torque tube drive. The main difference is that it uses an open propeller shaft running parallel to the torque arm, instead of a drive shaft housed within a torque tube.

d. Coil Spring and Control Rod Drive. This type of live axle suspension commonly is used in modern vehicles. In this configuration (fig. 30-7), the coil springs are placed between the axle housing and the frame. Their sole purpose is to support the weight of the vehicle. All torque reaction due to accelerating and braking and all

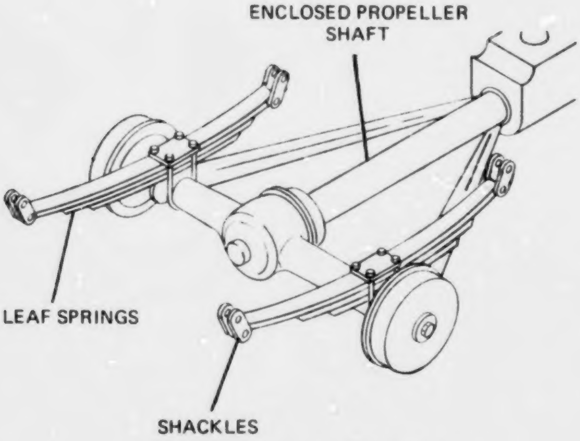


Figure 30-5. Torque Tube Drive.

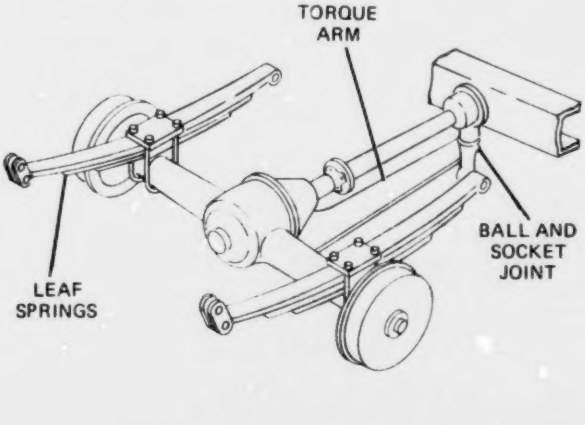


Figure 30-6. Torque Arm Drive. TA233802

558

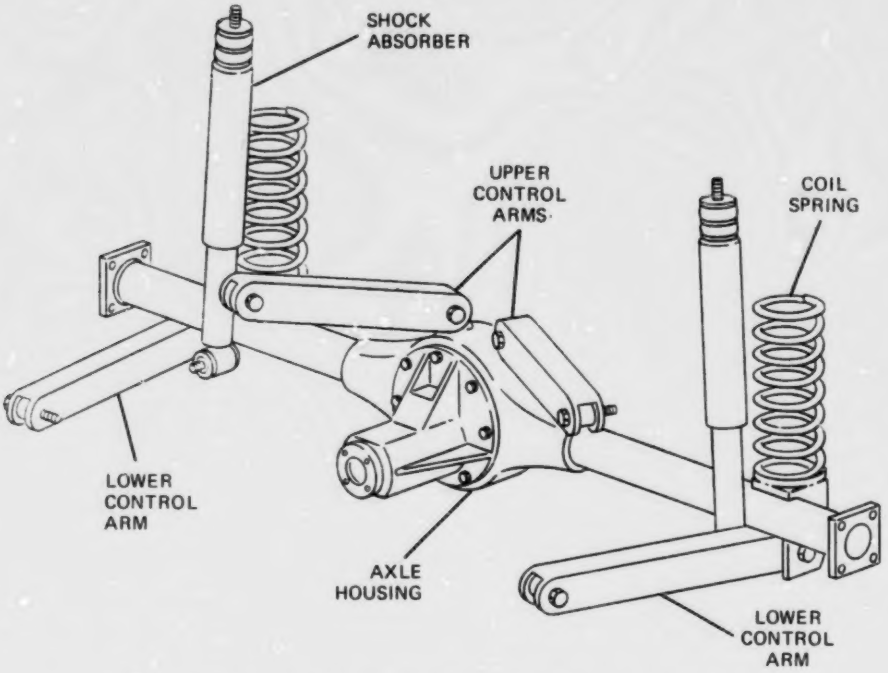


Figure 30-7. Coil Spring and Control Rod Drive.

driving thrust is absorbed and transmitted through control rods. The control rods, four in all, also are used to maintain the rear axle housing alinement to the frame. Two of the rods are mounted below the centerline of the axle, toward the outside of the rear axle housing and attached to the frame with bushings in the front. The remaining two are mounted inboard, above the centerline of the axle. As the vehicle accelerates, the axle housing will try to wind up, the upper control arms will be under tension, and the lower arms will be in compression, delivering the driving force to the frame. Under braking conditions, the opposite happens; the upper control arms are in compression and the lower arms are in tension, holding the body back.

e. Dead Front Axle. The dead front axle (fig. 30-8) supports the vehicle weight and resists the torsional stresses that occur during braking. To resist these stresses, as well as those resulting from impacts experienced during travel, and still maintain reasonable wheel alinement and directional stability, the dead front axle usually is attached to the frame by means of rather stiff semielliptic leaf springs. These springs produce a harsh ride and limit the vehicle speed over irregular terrain. Softer springs may be employed, in which case the axle guidance and torque resistance must be taken by separate linkages or other mechanisms.

To permit steering, the dead front axles are equipped with pivoting wheel spindles. The axles are usually I-sections of drop-forged alloy steel. The unsprung mass may be reduced, and the torque-resistance properties improved, by using more expensive tubular axles of molybdenum steel.

TA233803

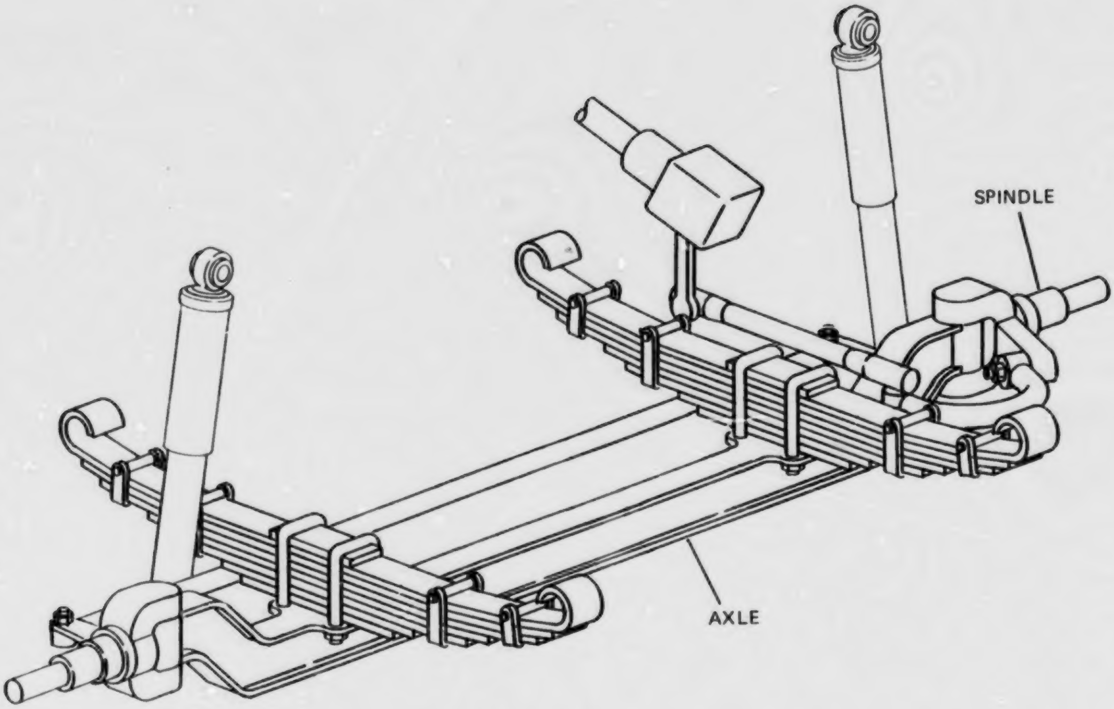


Figure 30-8. Dead Front Axle.

Section III. INDEPENDENT AXLE SUSPENSION SYSTEMS

30-5. Purpose. The term independent suspension is applied to a method of vehicle suspension in which each wheel supports its share of the vehicle load without the intermediary axle. Each wheel is free to oscillate independently of the other wheels. Either the front or rear wheels, or both, may be suspended independently. They may be driven or freewheeling. No one type of spring is used for independent suspensions. Leaf, coil, torsion bar, torsi-elastic, and pneumatic springs have been used. A variety of mechanisms have been devised in implementing the independent suspension.

30-6. Freewheeling Independent Suspensions. A typical independent front suspension for a light vehicle is shown in figure 30-9. In this design, each wheel is held in alinement by a pair of stiff control arms, commonly called parallel wishbones. The vehicle weight is transferred from the frame to the rigidly attached crossmember, through the coil spring, to the lower wishbone. It may be noted that the control arms are of unequal lengths. The vehicle designer may achieve certain desirable suspension and cornering characteristics by selecting the control arm lengths carefully.

30-7. Driven Independent Suspensions. The engine power is transmitted from the gearcase, which is attached to the vehicle frame rigidly, through half shafts, to each wheel. The geometry of the guiding linkage dictates the use of two universal joints. Because the gearbox is fastened to the frame rigidly, the driving torque reactions are taken through the frame and do not affect the suspension spring.

Figure 30-10 shows a parallel wishbone suspension for a heavy multiwheeled vehicle.

This design is similar to that of figure 30-11, except that torsion bar springs are used in place of coil springs.

An independent rear suspension employing coil springs is shown in figure 30-12. In this design, the alinement of each wheel is maintained by a

TA233804

560

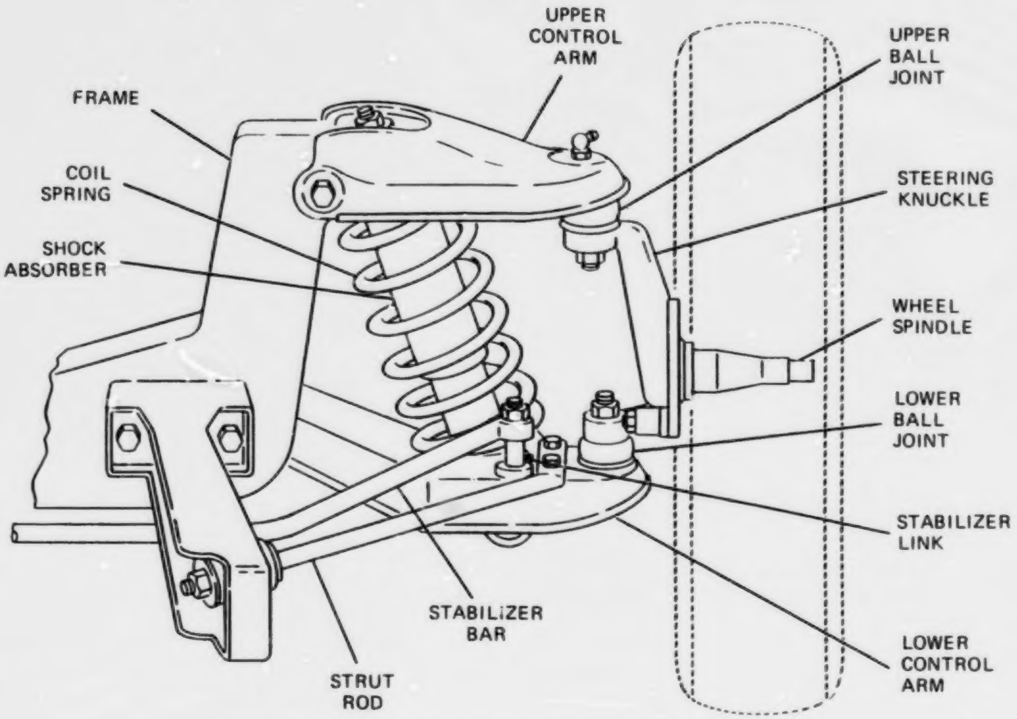

UPPER CONTROL ARM
FRAME
COIL SPRING
SHOCK ABSORBER
UPPER BALL JOINT
STEERING KNUCKLE
WHEEL SPINDLE
LOWER BALL JOINT
STABILIZER LINK
STABILIZER BAR
STRUT ROD
LOWER CONTROL ARM

Figure 30-9. Freewheeling Independent Suspension.

swinging-arm type of linkage. The arm consists of a rigid wishbone whose pivot axis is not necessarily parallel to the longitudinal axis of the vehicle. The wheel spindle is attached rigidly to the arm, which results in a tilting of the plane of the wheel, both longitudinally and vertically, when the suspension is displaced. The location of the swinging-arm pivot axis causes the rear wheels to produce a steering effort that improves the cornering characteristics of the vehicle. Two

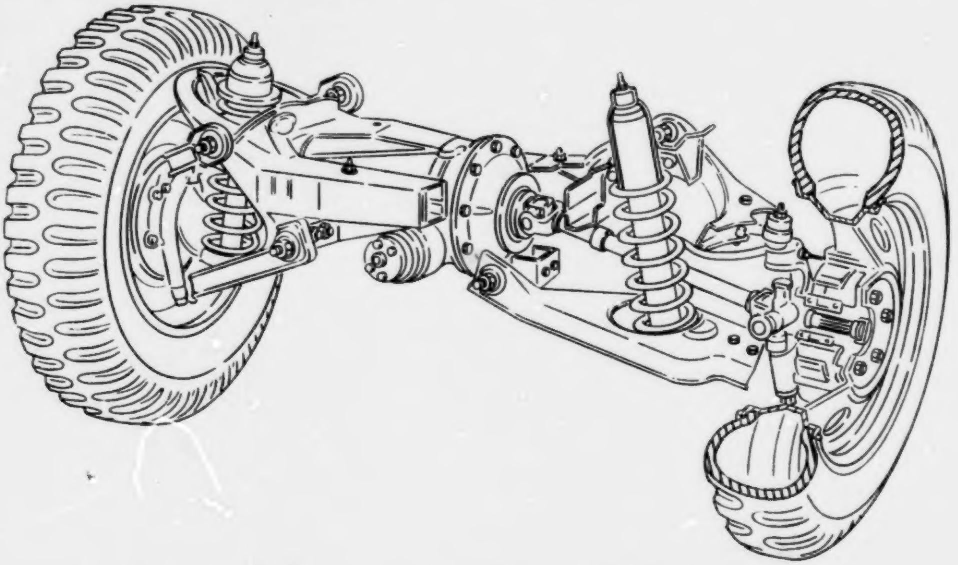


Figure 30-10. Driven Parallel Wishbone Coil Spring Front Suspension.

TA233805

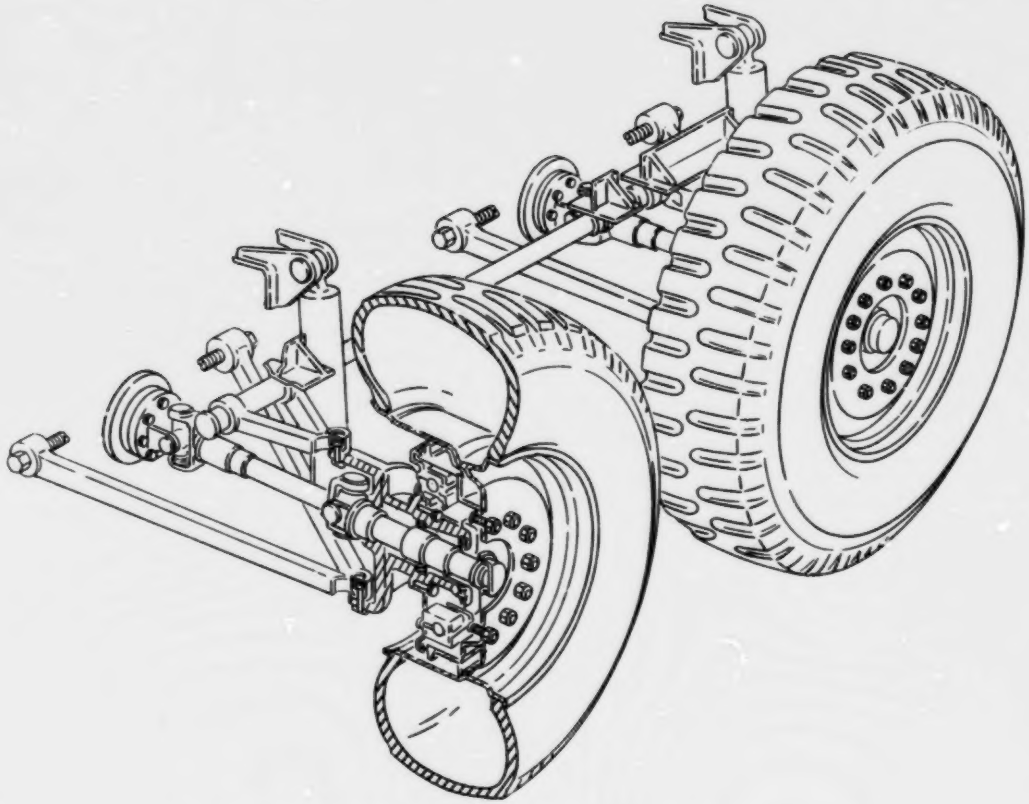


Figure 30-11. Driven Parallel Wishbone Torsion Bar Suspension.

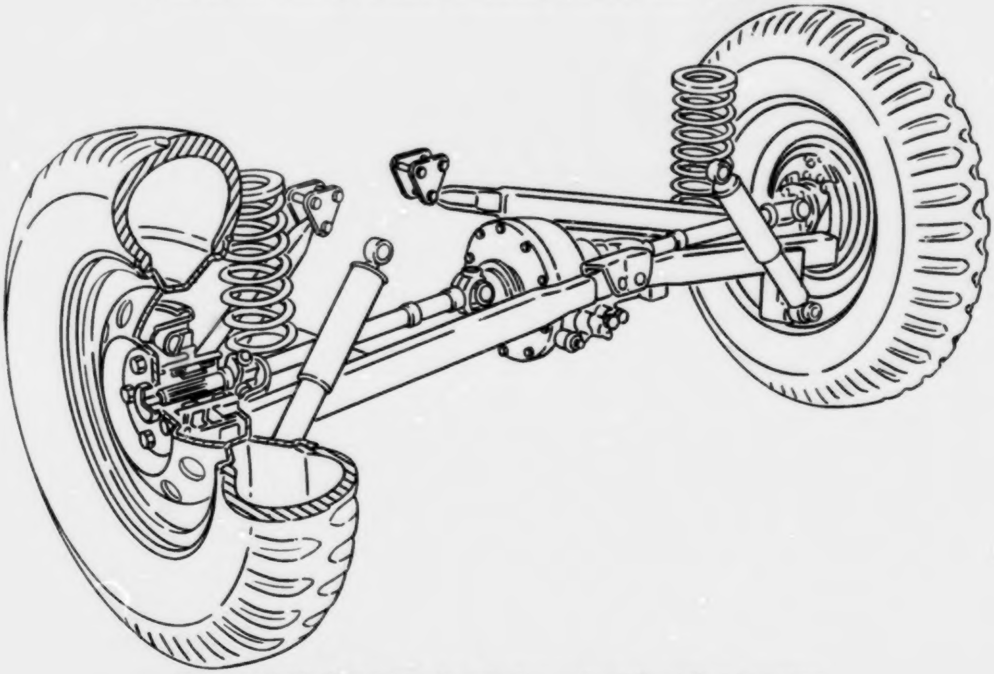


Figure 30-12. Swinging-Arm Independent Rear Suspension.

TA233806

562

universal joints are necessary in the power shafts of this design, because the swinging-arm pivot axis is out of line with the power shaft. The pivot axis, however, does pass through the inboard universal joint to minimize the relative sliding motion of the splined coupling.

30-8. MacPherson Struts. The MacPherson suspension system uses a tubular strut, which houses the shock absorber mechanism and links the wheel and body together (fig. 30-13). The strut usually is surrounded by a coil spring attached to the top of the strut, which is mounted to the body. The lower half of the spring is mounted by a flange that is attached to the bottom half of the strut, which is mounted to the spindle or control arm. There are also other types of configurations in which the spring is mounted next to the strut; this type makes replacement of the strut relatively easy.

30-9. Comparison. The development of the independent suspensions came about mostly to reduce the unsprung mass, thereby improving the handling and traction of high-speed road cars. However, the demand for greater speed and mobility for military vehicles warrants the use of independent suspension on such vehicles. In addition to the improved performance associated with reduced unsprung mass, the use of independent suspensions increases the speed and mobility of the military vehicle by reducing front end vibration (wheel shimmy and axle tramp), permitting the use of softer suspension springs, providing more ground clearance, and permitting more optimum wheel spacing.

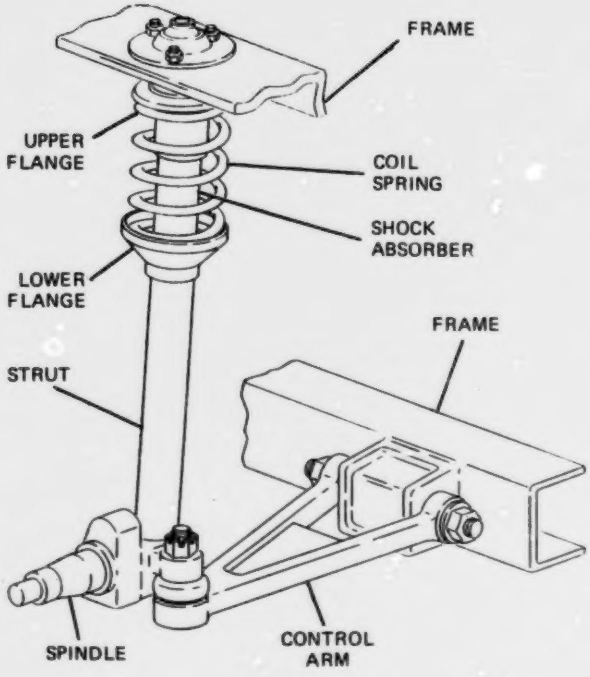


Figure 30-13. MacPherson Strut Suspension.

The disadvantages of independent suspensions for military vehicles are primarily those of cost and maintenance. The separate rigid members used to maintain wheel alinement require more careful design, expensive machining, and costlier bearings than the simple solid axle, leaf-spring suspension. The pivot bearings must be lubricated properly so that excessive clearances will not cause vibrations and disturbances in the steering and suspension systems. The independent suspension is not as rugged as the solid axle type, although continuing development of the independent suspension for military vehicles may minimize these disadvantages.

Section IV. HEAVY VEHICLE SUSPENSION

30-10. Springs. Several configurations of spring suspension have been used for vehicles that carry widely varying loads, to provide the necessary variable load rate.

a. Auxiliary springs, often called secondary springs (fig. 30-14), commonly are used in addition to the mainspring to accomplish this purpose. When the load on the spring reaches a certain amount, the deflection of the mainspring brings the free ends of the secondary spring against bearing plates on the frame, or on the axle if the secondary spring is secured to the frame. From that point on, the two springs carry the load jointly and their load ratings are added. This allows the vehicle to carry heavy loads without deflecting the mainsprings.

b. Another method of suspension that also provides a spring with variable load rating is shown in figure 30-15. The spring is made with flat ends that bear against curved bearing plates.

TA233807

563

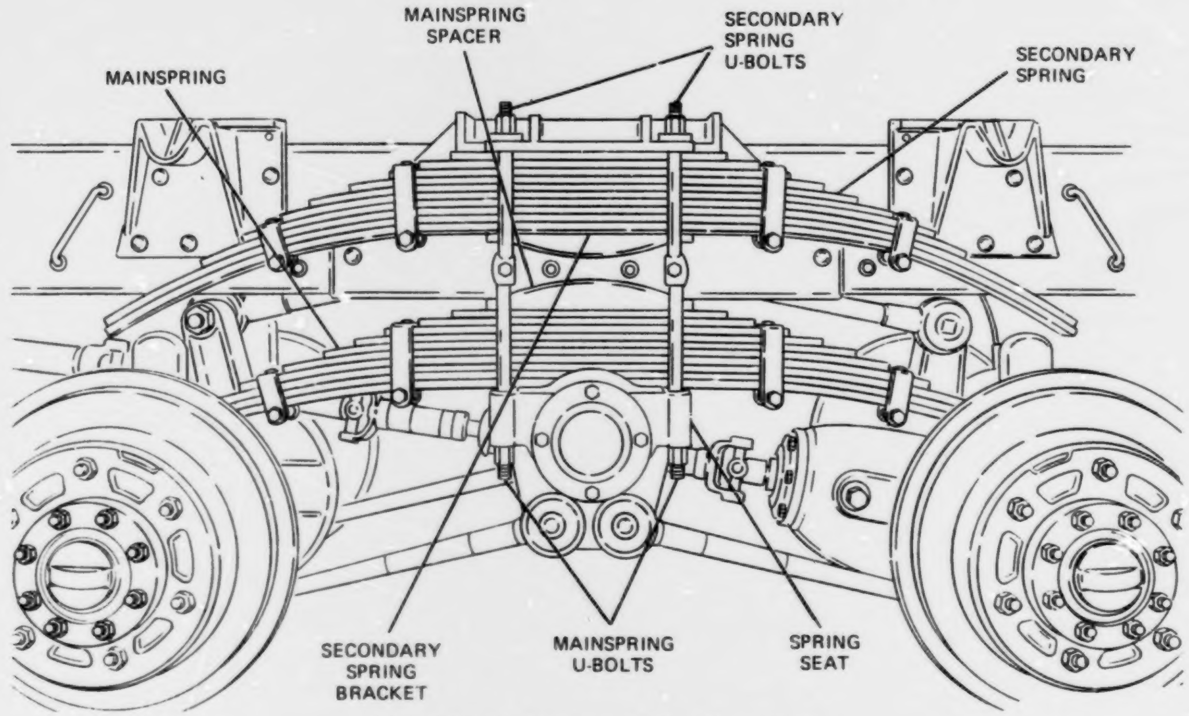


Figure 30-14. Auxiliary Spring Suspension.

With a light load, the springs make contact with the outer edges of the bearing plates; hence, the effective length of the spring is comparatively large and has a low load rating. Heavy loads deflect the spring, causing the points of contact to move toward the inner edges of the bearing plates. The effective length of the spring then becomes shorter, giving a higher load rating.

30-11. Axles. Two rear axles are used on numerous heavy vehicles to decrease the load on each rear wheel, decrease the effect of road shocks, and increase traction. A typical rear end on six-wheel vehicles consists of an axle mounted on each end of the rear springs. The load of the vehicle is applied at the center of the spring by means of a spring seat supported on the frame. The drive is applied to the foremost of the two axles, with the rear axle trailing, or it is applied to both axles by means of an interaxle differential, which ensures equal driving effort on both axles. The rear springs carry the same load they do with a single rear axle, but the load is distributed over two axles instead of one.

30-12. Bogie Axles. A large proportion of six-wheel vehicles have bogie axles. A bogie is a suspension unit, such as shown in figures 30-15 and 30-16, consisting of two axles joined by a single cross support (trunnion axle) that acts as a pivot for the entire unit. The tubular trunnion axle is attached rigidly to the frame through the mounting pads by two support brackets and the girder crossmember. The ends of each spring rest on hardened steel bearing plates on the two axle housings, the spring being supported on the vehicle frame by means of a spring seat on each end of the trunnion axle. Both springs are clamped on their spring seats by means of spring clips.

Both spring seats are mounted on a spindle on each end of the trunnion axle. Tapered roller bearings take side thrust imposed on the spring and allow it to pivot easily. Springs with very high load ratings must be used with this suspension because they carry the entire weight of the rear end. Mounting the springs on central pivots enables them to distribute half of the rear end load to each axle. As a result, the load on the rear of the vehicle is distributed over four wheels, allowing a vehicle to carry much heavier loads than a single rear axle vehicle without exceeding the safe tire load. When one wheel is deflected from a road shock, the spring pivots about its center so that both ends of the spring deflect to absorb the

TA233808

561

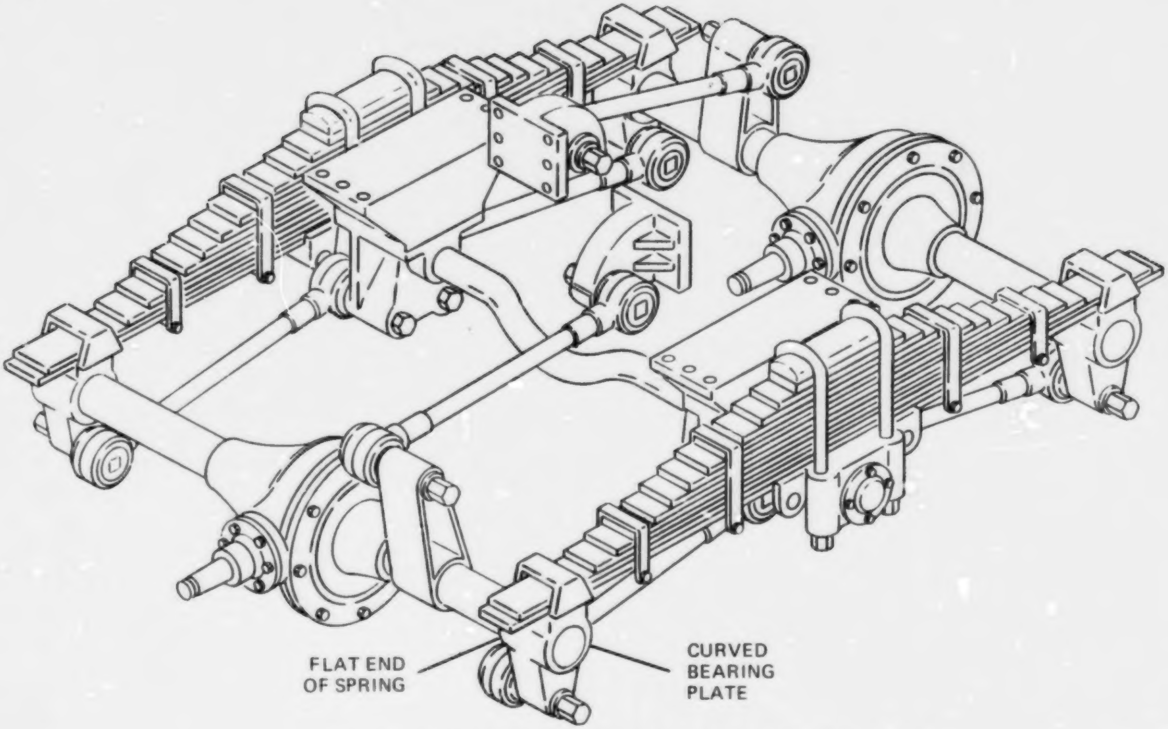

FLAT END
OF SPRING
CURVED
BEARING
PLATE

Figure 30-15. Variable Load Spring Arrangement.

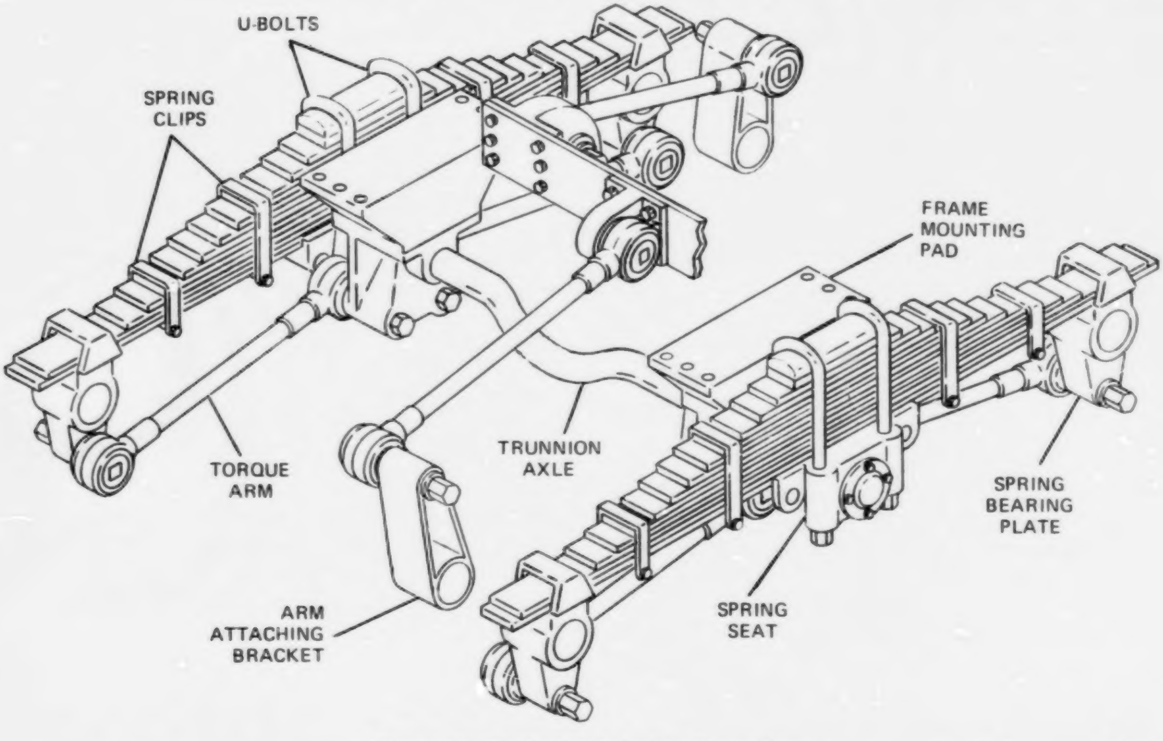

U-BOLTS
SPRING
CLIPS
FRAME
MOUNTING
PAD
TORQUE
ARM
TRUNNION
AXLE
SPRING
BEARING
PLATE
ARM
ATTACHING
BRACKET
SPRING
SEAT

Figure 30-16. Bogie Axle Configuration.

TA233809

energy of the road shock, rather than just one end. Thus, the effect of road shocks is cut in half. When only one axle is deflected up or down from its normal loaded position, the trunnion axle and the vehicle frame are raised or lowered half this amount. In this manner, bogie axles reduce by half the impact or shock not only to the vehicle, but also to the road.

Section V. AIR-OVER-HYDRAULIC SUSPENSION

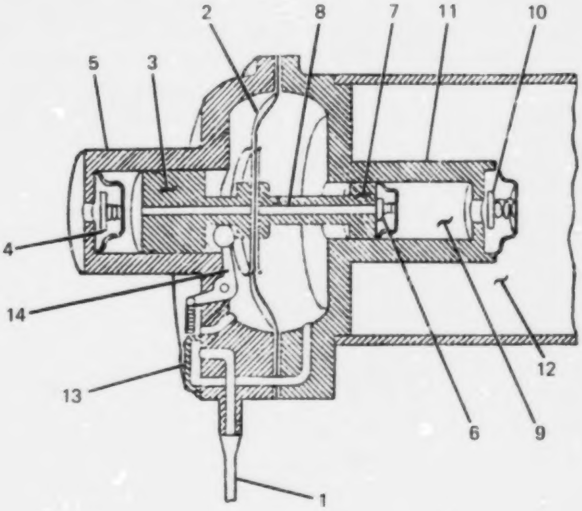
30-13. Purpose. The air-over-hydraulic suspension system is designed to keep the body level under different loading conditions. When the vehicle weight is increased, either by adding cargo or passengers, the body will become lower to the ground. The leveling system then will sense a low condition and allow pressure to increase in the special shock absorbers, raising the body with respect to the ground. When the weight is removed, the system will allow air pressure to bleed from the air shock absorbers, restoring the vehicle to its normal riding height.

30-14. Components of Air-Over-Hydraulic Suspension.

a. Air Compressor. The air compressor (fig. 30-17) is commonly a vacuum-operated two-stage unit requiring no lubrication. The sliding distributor valve directs intake manifold vacuum alternately to the right or left side of the diaphragm, moving it from side to side. When the diaphragm, which is connected to a double piston, moves to the right, it allows air to enter the first stage chamber. At the end of the stroke, the check valve on that chamber closes, and the distributor valve diverts the vacuum to the opposite side of the diaphragm. As the piston then moves to the left, the air in the first stage moves through the air passage in the center of the piston to the second stage chamber. At the end of that stroke. the check valve on the air passage closes and, as the piston moves to the right again, the check valve on the second stage cylinder opens, allowing the compressed air to enter the air reservoir tank. As pressure in the reservoir tank builds up to a predetermined amount, it puts an equal force on the second stage piston and the pumping action stops.

b. Pressure Regulator Valve. This component (fig. 30-18) regulates the air pressure to the height control valve to a predetermined amount, regardless of the pressure in the reservoir. The valve is nonadjustable and must be replaced if proper pressure is not maintained.

c. Height Control Valve. This valve (fig. 30-19) is attached to the frame of the vehicle, and linkage is used to attach the valve to the suspension system. When the frame moves downward because of additional weight, the intake valve is opened by the linkage, allowing pressure to increase in the shock absorber. This, in turn, raises the vehicle to its normal position. As soon as the vehicle is level, the intake valve closes and a steady pressure is maintained in the shocks. When weight is removed from the vehicle, the linkage opens the exhaust valve and pressure is released in the shocks, restoring the vehicle to a normal riding position. The linkage also is dampened through the use of a fluid to prevent the control valve from reacting to bumps and changes in road conditions.



1. VACUUM LINE
2. DIAPHRAGM
3. PISTON
4. CHECK VALVE
5. FIRST-STAGE HOUSING
6. CHECK VALVE
7. SECOND-STAGE END OF PISTON
8. AIR PASSAGE
9. SECOND-STAGE CYLINDER
10. CHECK VALVE
11. SECOND-STAGE HOUSING
12. AIR RESERVOIR TANK
13. SLIDING DISTRIBUTOR VALVE
14. ARM

Figure 30-17. Air Compressor. TA233810

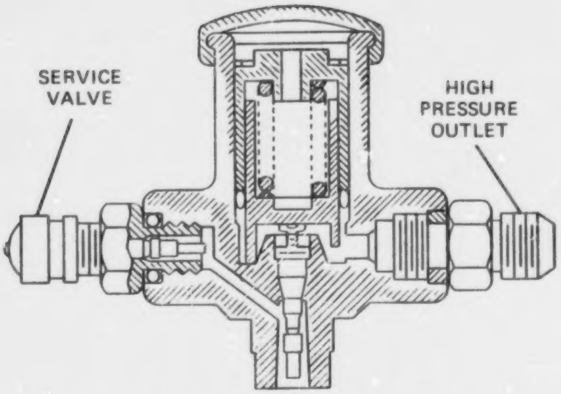

SERVICE VALVE
HIGH PRESSURE OUTLET

Figure 30-18. Pressure Regulator Valve.

30-15. Air Shock Absorbers. Air shock absorbers (fig. 30-20) are conventional hydraulic shock absorbers with an additional air chamber added to establish load-carrying capabilities. The air inlet to the shock absorber is connected to the air output of the height control valve. The air shock absorber uses a rubber boot to form the air chamber between the dust boot and reservoir tube. When the pressure is increased in the air chamber, it makes the shock absorber extend. When air is released, the shock is allowed to contract. The shock absorbers are connected by a crossover air line to keep the pressure in each the same. A small amount of pressure is maintained in the system to minimize boot friction.

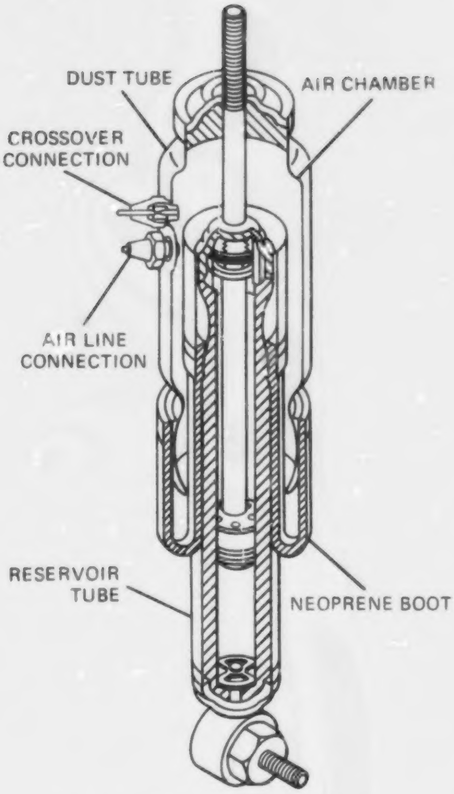
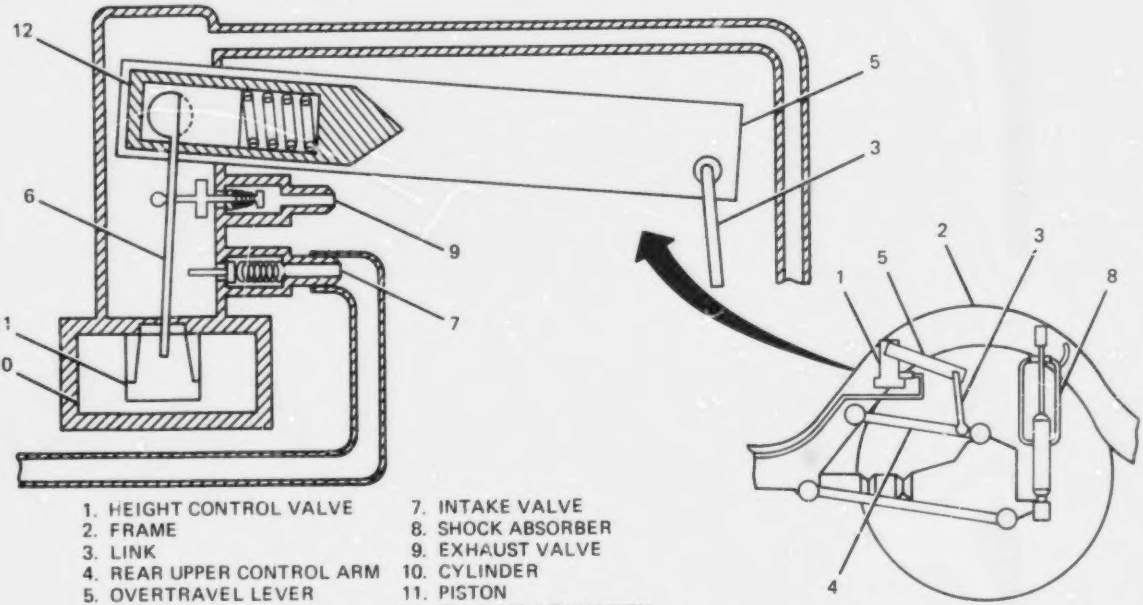

DUST TUBE
AIR CHAMBER
CROSSOVER CONNECTION
AIR LINE CONNECTION
RESERVOIR TUBE
NEOPRENE BOOT

Figure 30-20. Air Shock Absorber.


12
5
3
6
9
7
11
10
2
3
1
5
8
4

1. HEIGHT CONTROL VALVE
2. FRAME
3. LINK
4. REAR UPPER CONTROL ARM
5. OVERTRAVEL LEVER
6. INTERNAL LEVER
7. INTAKE VALVE
8. SHOCK ABSORBER
9. EXHAUST VALVE
10. CYLINDER
11. PISTON
12. PLUNGER MECHANISM

TA233811

Figure 30-19. Height Control Valve.

567

Section VI. SHOCK ABSORBERS

30-16. Purpose. The primary function of the shock absorber is to regulate the suspension spring rebound so that the primary vibrations are damped out, thereby permitting greater vehicle speeds and mobility. These benefits are achieved by virtue of reduced bouncing and pitching of the body or hull and reduced variations of the traction with the terrain. Additional benefits derived from the use of shock absorbers are: improved ride quality, reduction of wheel dance, prevention of excessive sidesway, reduction of wheel shimmy, and general improvement of the desirable vehicle traveling qualities, collectively termed roadability.

30-17. Classification of Shock Absorbers.

a. *Single Acting.* Shock absorbers are of two general classes: single acting and double acting. Those that check only spring rebound are termed single acting. They are so designed, or attached to the suspension system in such a manner, that the damping force is not generated during spring deflection. Their main disadvantage is that they provide damping only part of the time, imposing the requirement of stiffer springs in the system. Also, a slight preload on the suspension spring is experienced due to the shock absorber return spring. This has a tendency to stiffen the suspension spring out of proportion for mild terrain irregularities.

b. *Double Acting.* Those shock absorbers that provide damping during spring deflection as well as during rebound are termed double acting. They permit the use of softer suspension springs and allow optimum damping in both directions. In most cases, the damping force developed by the double-acting shock absorber during spring compression is much lower than is developed during rebound. This is desirable because a high damping force during spring compression would have the same effect on impact isolation as would a very stiff spring; that is, it would transmit the shock to the vehicle body, causing it to displace vertically. It is desirable not to interfere with the impact-isolating properties of the spring during its compression stroke, because there is no upper limit to the amount of acceleration that the vehicle body can experience when the ground-contacting elements pass over a vertical obstacle at high speed. For this reason, the larger damping force is exerted during rebound; that is, when the spring is being extended from the position to which it was compressed by the vertical impact.

There is some disadvantage in this arrangement when the moving vehicle hits a hole. The spring extends so that the ground-contacting elements can maintain good contact with the ground. The high damping force exerted by the shock absorber interferes with this action, resulting in a downward acceleration of the vehicle body. This is an acceptable condition, because the downward acceleration of the sprung mass cannot exceed the acceleration of gravity because no other downward force is acting on the sprung mass.

30-18. Types of Shock Absorbers.

a. *Single Acting, Cam Operated.* A typical single-acting, cam-operated shock absorber is shown in figure 30-21. When the sprung and unsprung masses of the suspension system move toward each other, the shock absorber arm rotates counterclockwise, moving the cam to the right, thereby permitting the piston spring to move the piston to the right. This causes the intake valve in the piston to open, allowing oil to flow from the reservoir into the increasing cylinder volume. Because the piston motion and oil flow are caused by the piston spring, the shock absorber has little effect upon the spring action of the vehicle. During rebound, the cam moves to the left, forcing the piston to the left against the oil in the cylinder. The intake valve closes, and the oil in the cylinder is forced out through the relief valve. The restricted passage of the oil through the relief valve orifice is the primary factor in generating the damping force during rebound.

b. *Vane Type.* The housing of the vane-type shock absorber, shown in figure 30-22, is divided into two working chambers by stationary partitions, each of which contains a check valve. The central shaft is connected to the unsprung mass through the arm and link, and has a pair of vanes attached to it that extend into each working chamber. As the suspension spring is compressed, the central shaft rotates, and the vanes develop a pressure in the chamber that causes oil to flow unrestricted through the opened check

568

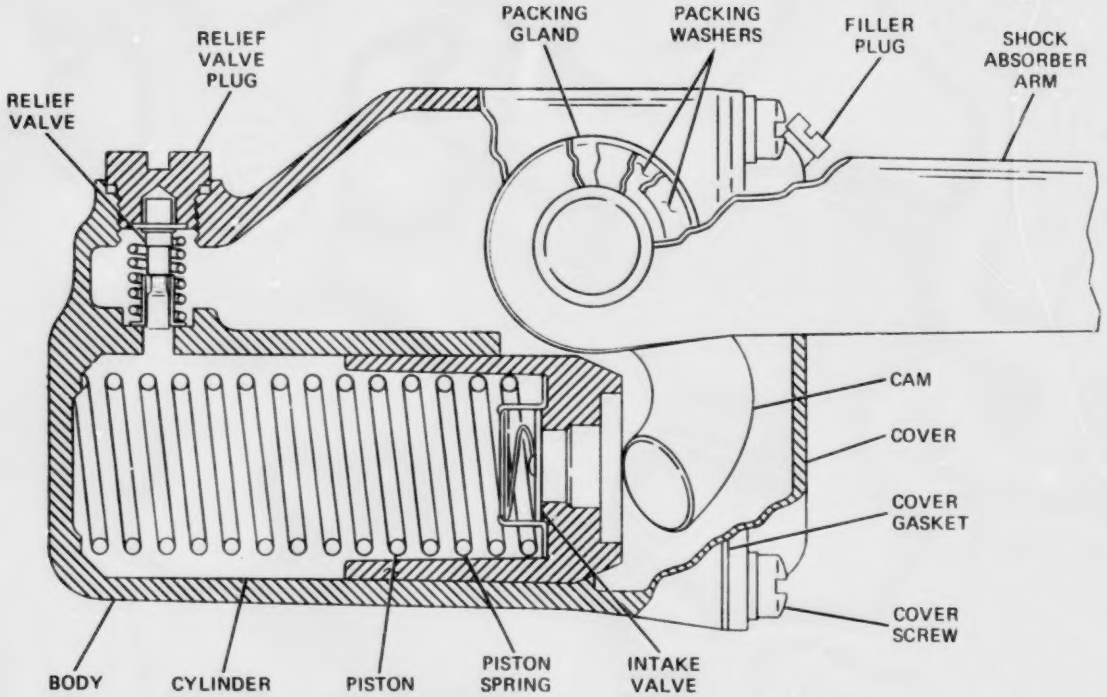

RELIEF VALVE
RELIEF VALVE PLUG
PACKING GLAND
PACKING WASHERS
FILLER PLUG
SHOCK ABSORBER ARM
CAM
COVER
COVER GASKET
COVER SCREW
BODY
CYLINDER
PISTON
PISTON SPRING
INTAKE VALVE

Figure 30-21. Single-Acting Cam-Operated Shock Absorber.

valves in the stationary partitions. On the rebound stroke, the vanes develop a pressure on the opposite side, closing the check valves. Because oil cannot flow through the check valves, it is forced through the needle valve in the center of the shaft, thereby producing a resistance to motion of the arm. The vane-type shock absorber is not used widely, primarily because of the high cost and poor reliability resulting from the difficulty in sealing this type.

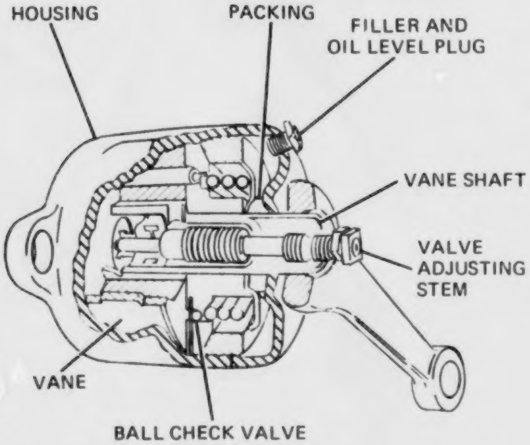

HOUSING
PACKING
FILLER AND OIL LEVEL PLUG
VANE SHAFT
VALVE ADJUSTING STEM
VANE
BALL CHECK VALVE

Figure 30-22. Vane-Type Shock Absorbers.

c. Direct Acting. The direct-acting shock absorber (fig. 30-23) consists of an inner cylinder filled with a special shock absorber oil, divided into an upper and lower chamber by a double-acting piston. The shock absorber is mounted by studs and rubber bushings inserted through the eye on each end so that it is acted directly upon by spring action. The piston push rod, therefore, is forced up and down within the inner cylinder. A reservoir that contains an ample supply of oil surrounds the inner cylinder and is joined to it by a reservoir check valve. When the vehicle spring is compressed, the piston is forced down, and some of the oil below the piston is forced through compression valves (only one is illustrated in figure 30-23) inside the piston to the upper chamber. These valves operate only on the downstroke. Because the push rod moves into the cylinder on the downstroke, some of the oil in the lower chamber is forced through the check valve at the bottom of the cylinder into the reservoir.

When the vehicle spring rebounds, the piston is moved up, and oil from the upper chamber is forced into the lower chamber through spring-loaded rebound valves inside the piston. These valves control the rebound of the vehicle spring.

TA233812

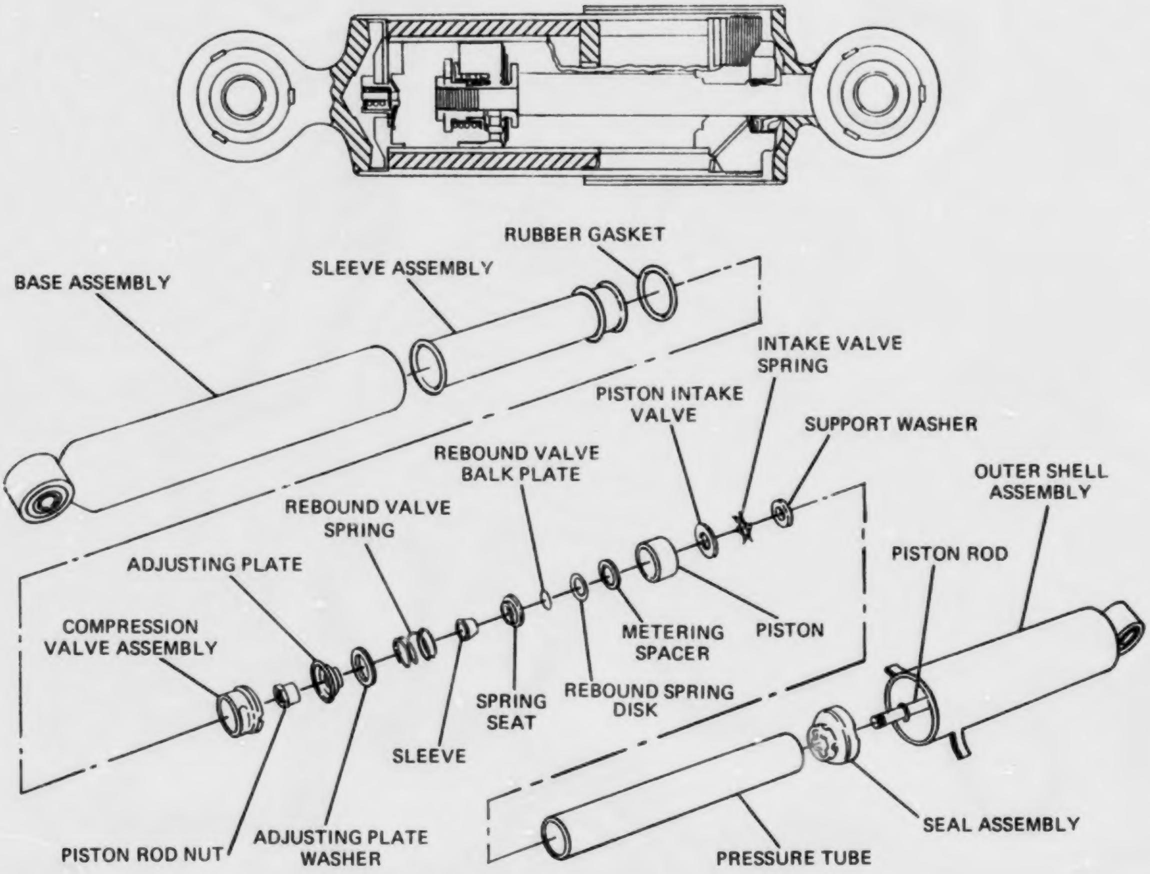

RUBBER GASKET
BASE ASSEMBLY
SLEEVE ASSEMBLY
INTAKE VALVE SPRING
PISTON INTAKE VALVE
SUPPORT WASHER
REBOUND VALVE BALK PLATE
OUTER SHELL ASSEMBLY
REBOUND VALVE SPRING
PISTON ROD
ADJUSTING PLATE
COMPRESSION VALVE ASSEMBLY
METERING SPACER
PISTON
SPRING SEAT
REBOUND SPRING DISK
SLEEVE
SEAL ASSEMBLY
PISTON ROD NUT
ADJUSTING PLATE WASHER
PRESSURE TUBE

Figure 30-23. Direct-Acting Shock Absorber.

As the piston moves out of the cylinder, oil is drawn into the lower chamber from the reservoir through the reservoir check valve.

An outer metal cover protects the shock absorber from damage by stones that may be kicked up by the wheels. Rubber bushings are fitted on both sides of the eye to prevent metal-to-metal contact with the mounting stud or bolt. Direct-acting shock absorbers require no care and attention and are not repairable.

Section VII. AUXILIARY UNITS

30-19. Torque Arms. When power and brake effort are applied, there is a tendency for the entire axle and spring assembly to rotate. To prevent this, strengthening arms are added to the axles. These are known as torque arms, torque rods, and torque tubes. The function of these three is the same, the major difference being that the torque tubes connect with the power train, whereas the other two connect with the frame of the vehicle. Parallel torque arms (fig. 30-6), used between axles in bogie suspensions, ensure correct spacing and alinement of the axles, prevent transfer of weight from one axle to the other (or the tendency of one axle to dig in more than the other), and help to avoid uneven tire wear and jumping axle when brakes are applied.

30-20. Swaybars. A vehicle tends to roll outward when turning, particularly at high speeds. To prevent this roll, swaybars or stabilizers (fig. 30-9) are used. The swaybar consists of a bar of alloy steel mounted across the chassis and secured to the frame through rubber bushings with arms on each end connected to the axle or

TA233813

independent suspension arms. When one side of the vehicle rises faster than the other, the twist set up on the swaybar reacts on the axle or independent suspension arms, tending to keep the frame level. If both sides rise equally, no twist is set up in the swaybar.

30-21. Pusher Axle. The pusher axle (fig. 30-24) is a nondriving axle. It is used in conjunction with the standard suspension to increase the load-bearing capabilities of larger vehicles. The axle is raised and lowered by the operator using controls located inside the cab. It is operated by varying air pressure in air suspension bags, mounted between the axle and the frame. The air bags serve to lower the pusher axle, force the axle against the road, and distribute loads evenly between wheels. Because of a lack of inherent dampening capabilities, shock absorbers also are used with the pusher axle. The shock absorbers stabilize fluctuations in the air bags caused by road surface characteristics. Air cylinders are used to raise the axle, and chains are used to secure the axle in a stowed position when not in use.

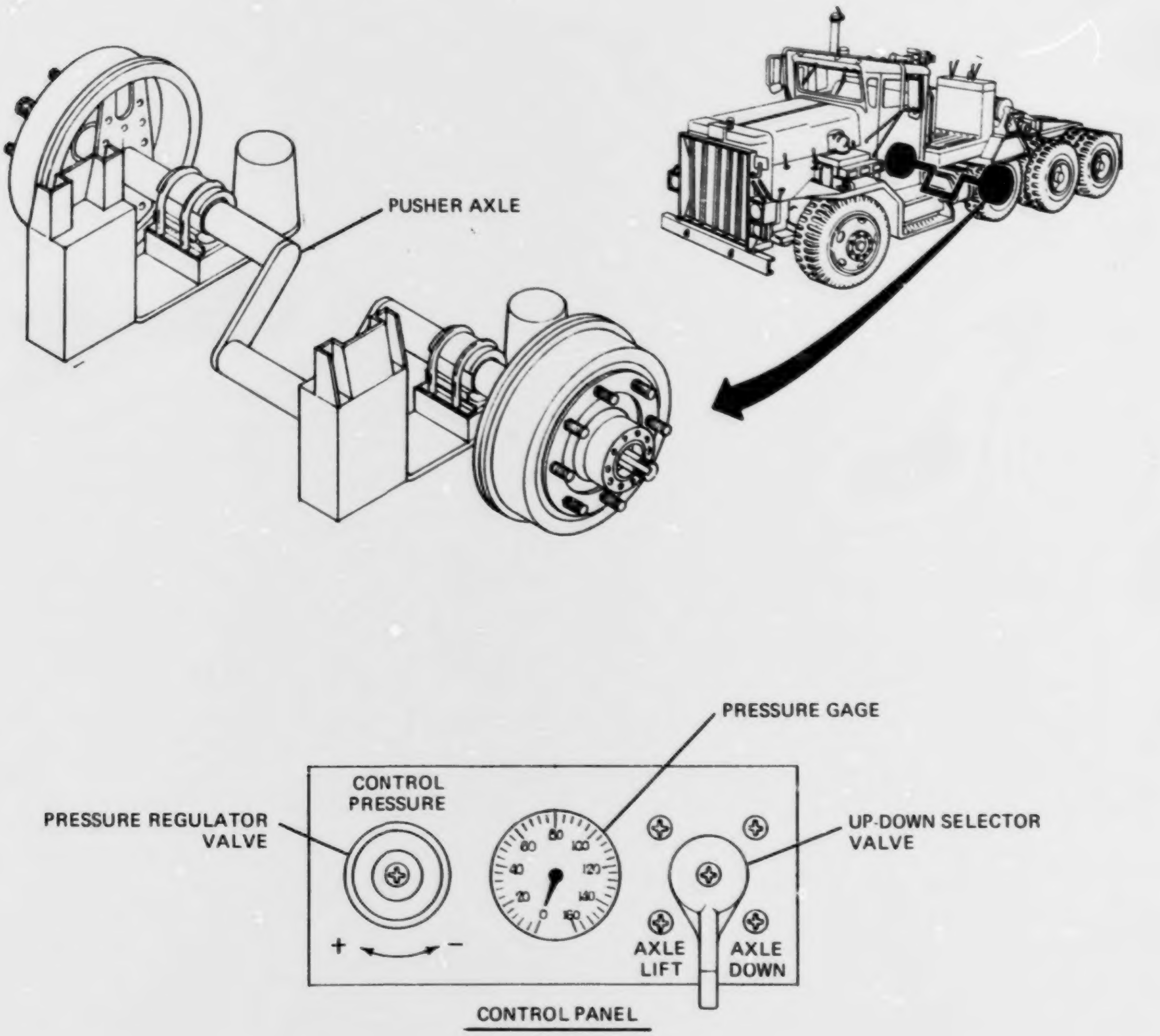

PUSHER AXLE
PRESSURE GAGE
CONTROL PRESSURE
PRESSURE REGULATOR VALVE
+
−
20
40
60
80
100
120
140
160
0
UP-DOWN SELECTOR VALVE
AXLE LIFT
AXLE DOWN
CONTROL PANEL

Figure 30-24. Pusher Axle and Controls.

TA233814

CHAPTER 31

SUSPENSION SYSTEMS IN TRACKED VEHICLES

Section I. PRINCIPAL PARTS

31-1. Springs.

a. Volute. The volute spring (fig. 31-1) consists of a wide strip of steel, tapered both in width and in thickness, wound to form a distorted spiral. Each coil overlaps the adjacent coil, with the widest and thickest part having the greatest diameter. The spring usually is wound so that adjacent coils rub, thereby producing frictional forces that tend to damp out oscillations. As the spring is compressed, its resistance increases because the heavier coils are brought into play. This characteristic protects the spring from overload. This type of spring is desirable when heavy loads must be supported, and space limitations prohibit the use of conventional springs.

b. Torsion Bars. The torsion bar spring used in tracked vehicles (fig. 31-2) has the same characteristics as the automotive type discussed in paragraph 30-2c. When the spring is employed in the tracked vehicle, it must support a greater weight, and usually is made thicker and longer than the automotive type.

31-2. Road Wheels. The tracked vehicle rolls on the bottom of its tracks by means of road wheels (fig. 31-3). For the most part, road wheels are steel disk type and of riveted or welded construction. Forged aluminum road wheels also have been developed, thus aiding in the reduction of the vehicle's weight. Solid rubber tires are laminated to the road wheels to absorb the shocks as the vehicle moves. This also serves to quiet the interaction between the road wheel and track. There is also a space between the road wheel that provides a channel in which the track center guides travel. The center guides aline the track and serve to keep it on the vehicle.

31-3. Idler Wheels and Track Support Rollers. Idler wheels, mounted on an arm assembly, are installed at the front of the vehicle (fig. 31-4). These assemblies are linked to the front road wheel support arms by track adjusting link assemblies. As the front road wheel support arm is moved upward by a bump or obstruction, the track adjusting link assembly swings the compensating idler arm towards the front to take up the slack in the track. The track adjusting link assembly may be lengthened or shortened to adjust the amount of track tension. The track support rollers hold up the returning track and prevent excessive sag. They may be rubber coated to reduce noise and help minimize vibration. The number of track support rollers that is used on a vehicle depends upon the type and length of track to be supported.

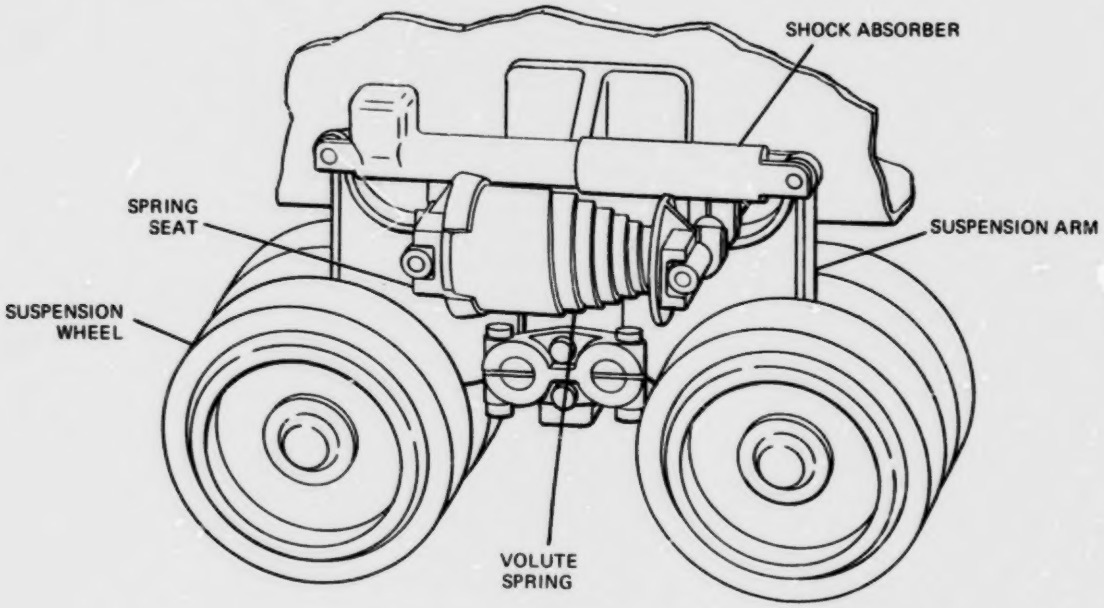

SHOCK ABSORBER
SPRING SEAT
SUSPENSION ARM
SUSPENSION WHEEL
VOLUTE SPRING

Figure 31-1. The Volute Spring.

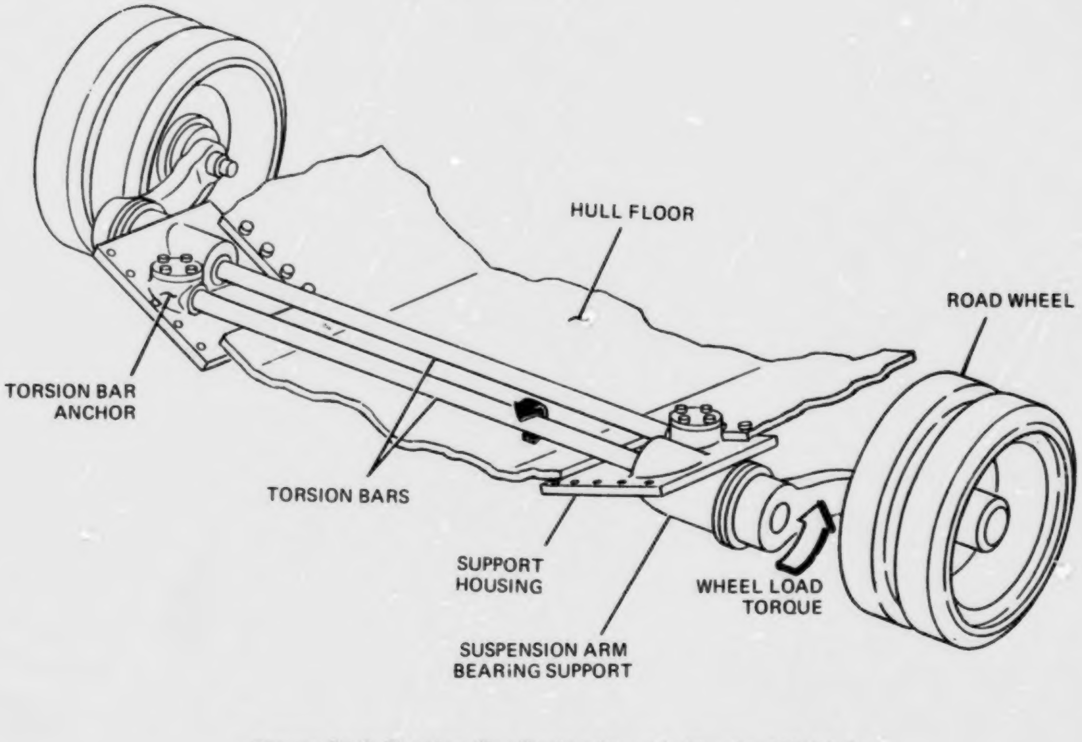

HULL FLOOR
ROAD WHEEL
TORSION BAR ANCHOR
TORSION BARS
SUPPORT HOUSING
WHEEL LOAD TORQUE
SUSPENSION ARM BEARING SUPPORT

Figure 31-2. Torsion Bar Spring Used in Tracked Vehicles.

TA233815

573

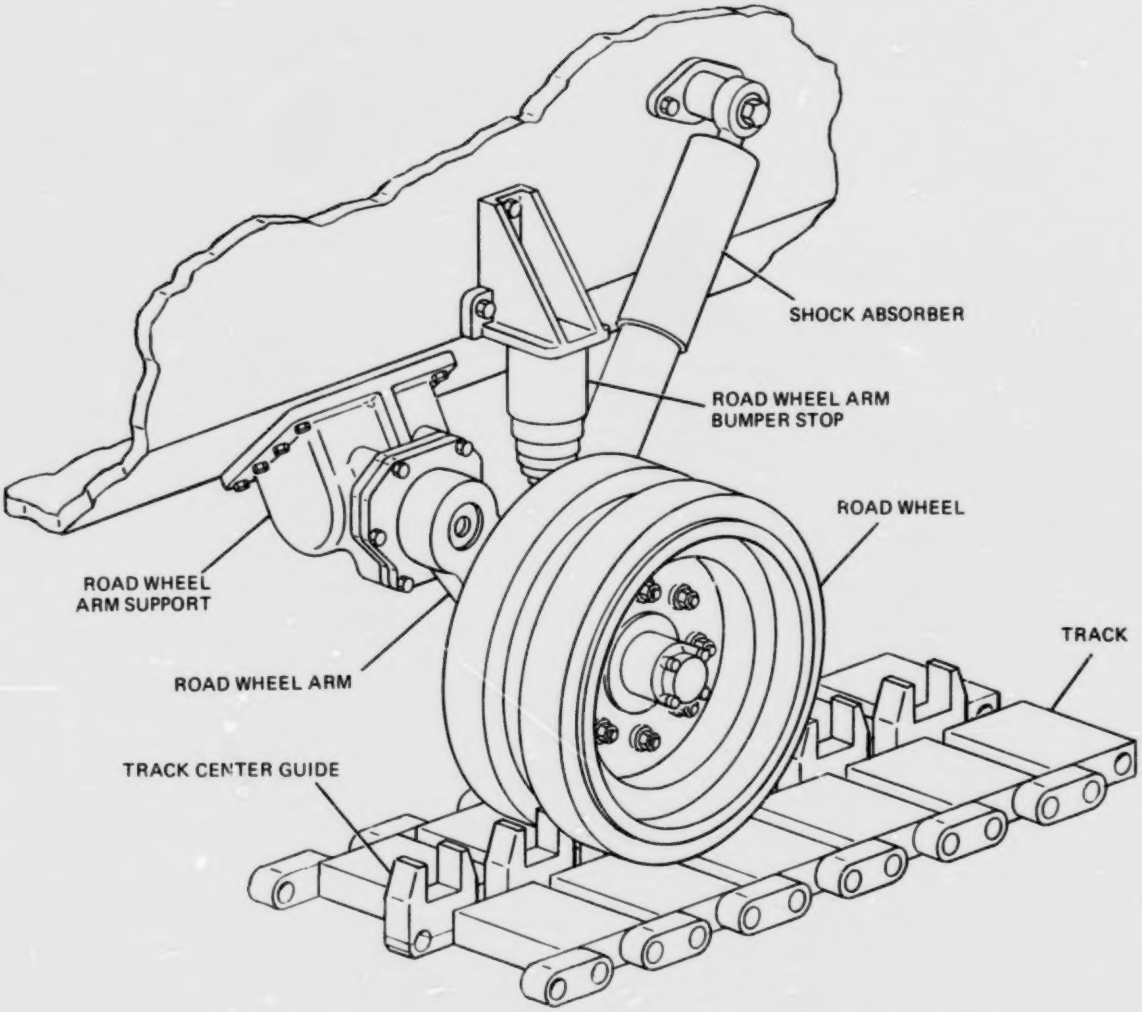

SHOCK ABSORBER
ROAD WHEEL ARM BUMPER STOP
ROAD WHEEL
ROAD WHEEL ARM SUPPORT
TRACK
ROAD WHEEL ARM
TRACK CENTER GUIDE

Figure 31-3. Road Wheels.

TA233816

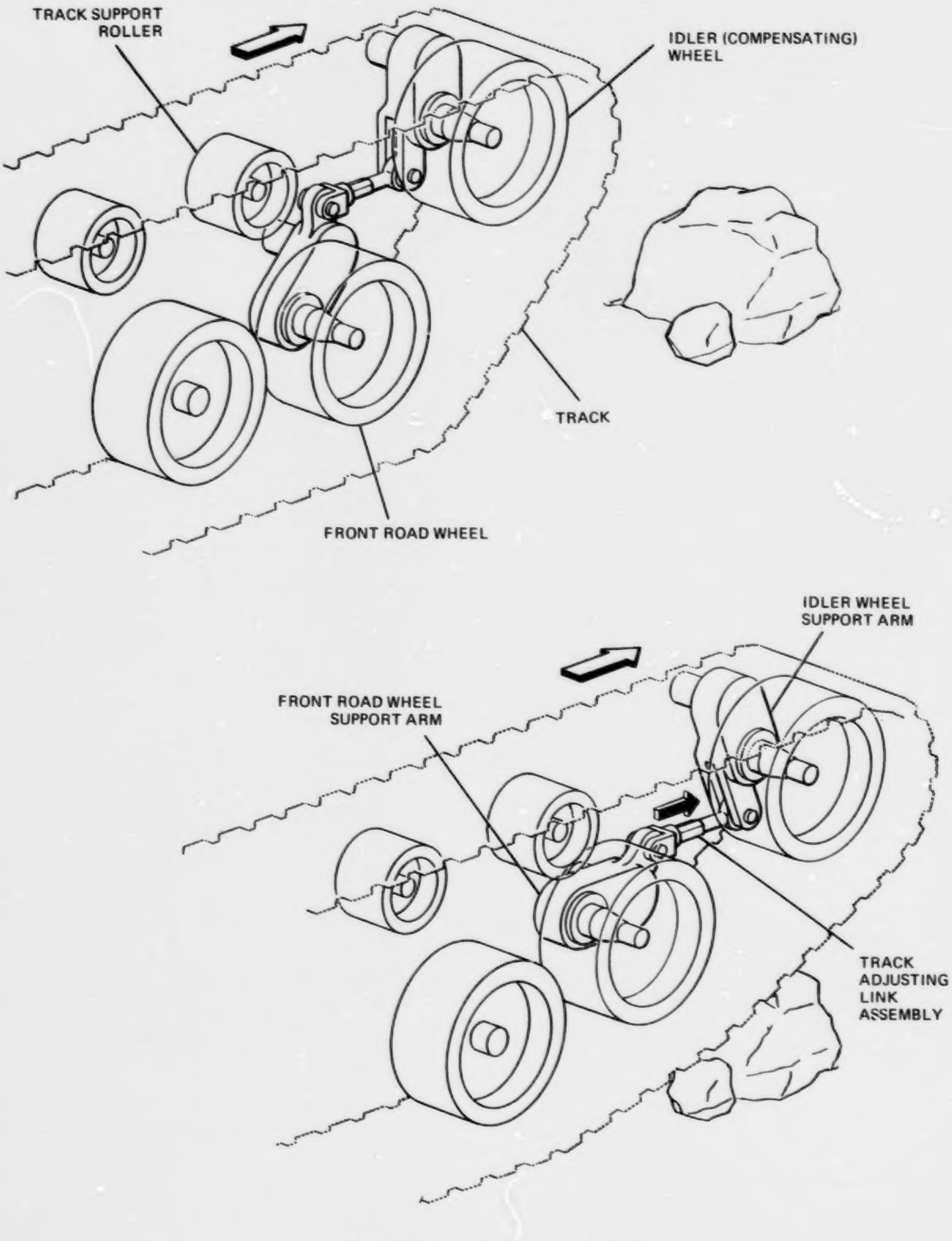

TRACK SUPPORT ROLLER
IDLER (COMPENSATING) WHEEL
TRACK
FRONT ROAD WHEEL
IDLER WHEEL SUPPORT ARM
FRONT ROAD WHEEL SUPPORT ARM
TRACK ADJUSTING LINK ASSEMBLY

Figure 31-4. Idler Wheel Operation.

TA233817

Section II. CONFIGURATIONS

31-4. Torsion Bar Suspension. The torsion bars generally are mounted inside the vehicle and extend completely across the width of the hull. Because of this configuration, the springs are protected from damage such as road hazards and, to some extent, land mines. Road wheels are mounted to crank-shaped arms connected to the hull through antifriction bearing mountings, which relieve the springs of all except the torsional loads (fig. 31-2). One end of a torsion bar is splined to the pivoting axle of each suspension arm. The other end of the bar is secured rigidly to the opposite side of the hull. The means of securing the stationary end of the torsion bar are well suited to applying mechanisms for varying the spring preload, thereby providing a means for adjusting the freestanding position of the vehicle to best suit the operating conditions. Angular displacement of the suspension arm is resisted by the torsional spring force of the bar. Because the arms operate in sealed antifriction bearings, and because of the lack of friction in the spring, little natural damping of the spring system is available. This condition makes the use of shock absorbers essential to minimize bouncing and pitching of the vehicle.

31-5. Horizontal Volute Spring Suspension. In the horizontal volute spring suspension (fig. 31-1) the spring is located between bellcranklike suspension arms. When a load is applied to the bogie wheels, the suspension arms pivot upward, transmitting the force directly to the spring, thereby compressing it. Vertical displacement of only one road wheel changes the spring load, thereby changing the load on the other wheel. The balance of forces in the suspension mechanism results in a wheel motion that is a combination rocking motion and vertical deflection.

31-6. Suspension Snubbers. Volute suspension snubbers are mounted on brackets bolted to the hull above each road wheel position (fig. 31-3). The volute springs serve to cushion road wheel arm bottoming shock loads. Inboard stub spindles on the support arms contact the springs near the upper limit of the support arm travel. A double volute spring is used for the front road wheel arm, and a single volute spring at the other road wheel arm positions.

31-7. Shock Absorbers. Suspension systems in tracked vehicles employ either direct-acting, cam and lever, or double-acting shock absorbers, which are discussed in chapter 30, section VI.

Section III. SUSPENSION LOCKOUT SYSTEM

31-8. Purpose. The basic function of a suspension lockout system is to bypass the suspension system and attempt to lock the vehicle to the ground. When the system is used in combat vehicles, it allows large guns to be fired from relatively light vehicles because the recoil is transmitted directly to the ground with minimum carriage movement. Suspension lockout systems also are used on lifting vehicles. When the system is activated on such vehicles, it allows the operator to maneuver large objects without the suspension compressing and possibly tipping over the vehicle.

31-9. Hydraulic Lockout System.

a. *Operating Principles.*

(1) This unit uses a hydraulic cylinder designed to combine lockout, damping, and bump-stop functions for each road wheel arm.

(2) Damping is controlled through a three-way valve mounted in the driver's compartment.

(3) Control pressure is supplied from a hydraulic accumulator, through the three-way valve and a reducing valve to a common line, which supplies all of the lockout cylinders.

(4) To lock the cylinder, control pressure is applied to the spool, depressing the spring until the spool land closes the right-hand ports in the rod, trapping the fluid in both ends of the cylinder.

b. *Construction.* The construction of the system is that of a double-rod-end cylinder with passages into the valve region in the rod from opposite sides of the piston. In the open position, the valve spool is preloaded by the spring against a hollow sleeve stop.

31-10. Hydromechanical Lockout System.

a. Operating Principles. The hydromechanical lockout system (fig. 31-5) is a suspension-damping device that incorporates a suspension lockout. Basically, the damping device is a frictional damper (disk brake) to which a hydraulic actuating cylinder is added. The hydraulic-actuating cylinder or brain box supplies and controls the pressure to the frictional damper where the energy absorption takes place. As the road wheel moves up or down, the brain box develops pressure through the use of a piston rod, which is connected to the road wheel arm through linkage. The pressure developed is routed to the frictional damper, which forces the stators and rotors together, creating a frictional resistance which retards the movement of the road wheels.

b. Construction. The hydromechanical lockout system is constructed of the following:

(1) The system uses linkage to connect the road wheel arm to the hydraulic actuating cylinder.

(2) The actuating cylinder controls the rate of damping the system will produce.

(3) The flutter valve directs the pressurized fluid to the pistons in the frictional damper.

(4) The frictional damper contains the frictional plates, which, when compressed, resist the movement of the road wheel arm.

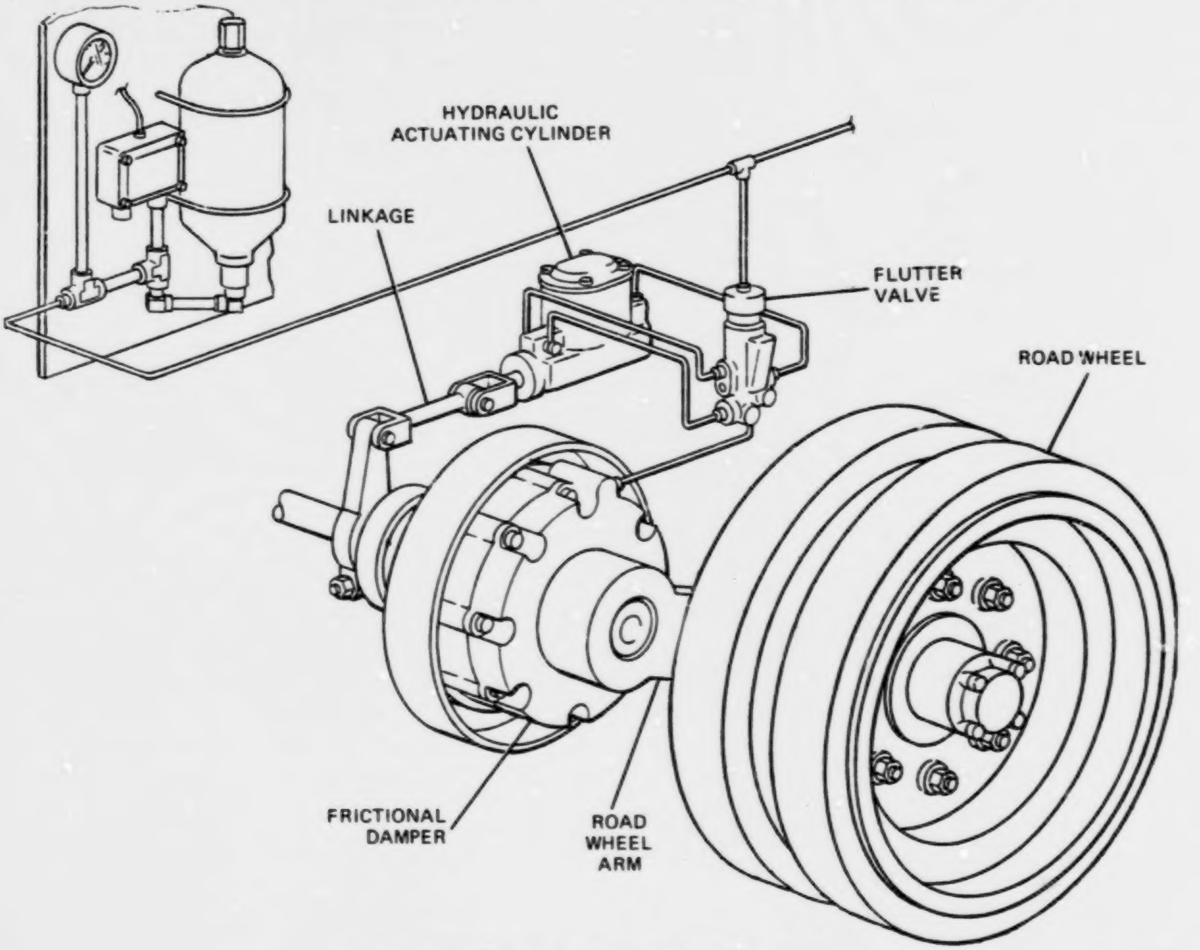


Figure 31-5. Hydromechanical Lockout System. TA233818

Section IV. SPADE SYSTEM

31-11. Construction and Operation. The spade system (fig. 31-6) is another form of anchoring the vehicle to the ground while a projectile is being fired. The spade system usually is mounted in the rear of the vehicle and transmits the force due to the recoil of the gun during firing into the ground. The spade is shaped like a bulldozer blade and has projections on the bottom to penetrate hard soil.

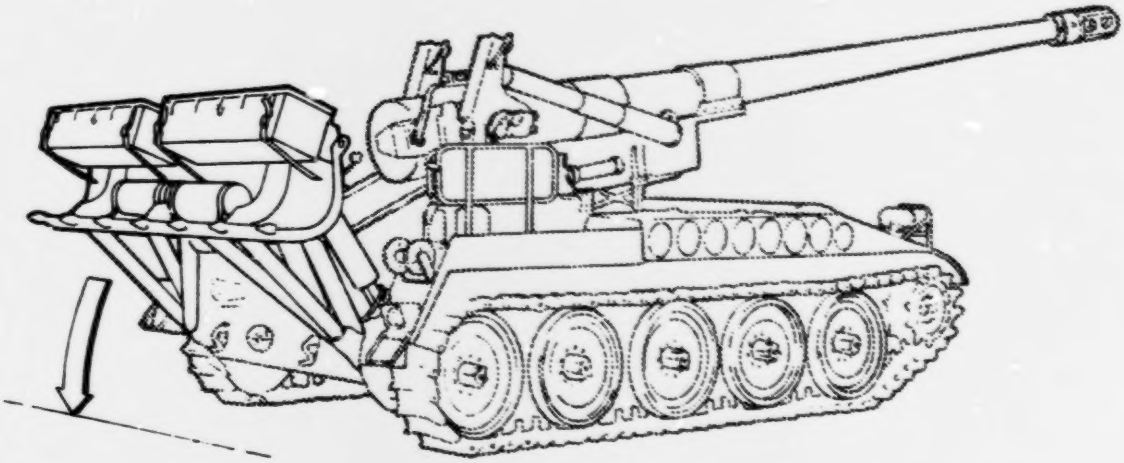


Figure 31-6. The Spade System.

TA233819

578

CHAPTER 32

WHEELS, TIRES, AND TRACKS

Section I. WHEEL CENTER SECTION

32-1. Disk Wheels. The center disk of a wheel (fig. 32-1) may be a solid plate or of a slotted steel construction. In both cases, the disk is welded or riveted to the rim, and the wheels are demountable at the hub. The disk is dished to bring the point of ground contact under the large wheel bearing, and to permit the mounting of dual wheels. Modern passenger cars almost exclusively use the steel-disk type wheel.

32-2. Pressed and Cast Spoked Wheels. On light vehicles, the wheel center section and rim are connected by spokes and the wheels are demountable at the hub. For heavier trucks, the spokes are integrated with the center section and a demountable rim is used. Another form of cast wheel (fig. 32-2), sometimes called a mag wheel, is a one-piece design made of lightweight alloys. These types of wheels are very popular on modern automobiles and are made in many sizes and styles. Great care must be taken when mounting and demounting tires on these rims, because the wheel assemblies are soft and brittle, which causes them to crack easily.

32-3. Wire Wheels. This type of wheel consists of a pressed-steel hub and rim connected by welded spokes (fig. 32-3). This design allows greater amounts of air to flow past the brake assemblies, therefore keeping them cool and minimizing brake fade. Wire wheels, however, are hard to clean, require the use of full-circle antiskid chains only, and are not adapted for use with dual wheels.

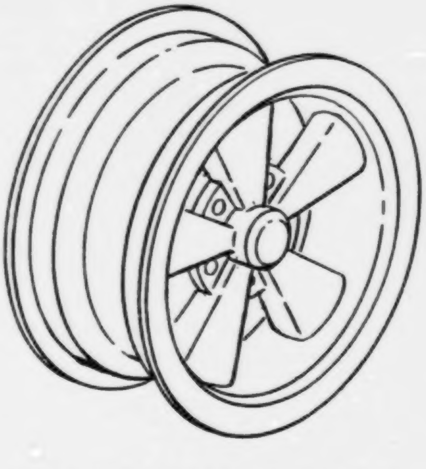


Figure 32-2. Cast Aluminum Wheel.

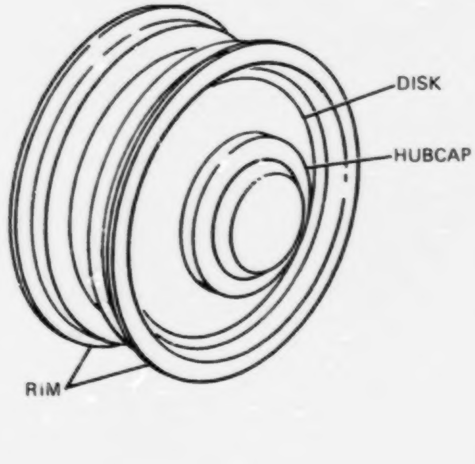


Figure 32-1. Disk Wheel.

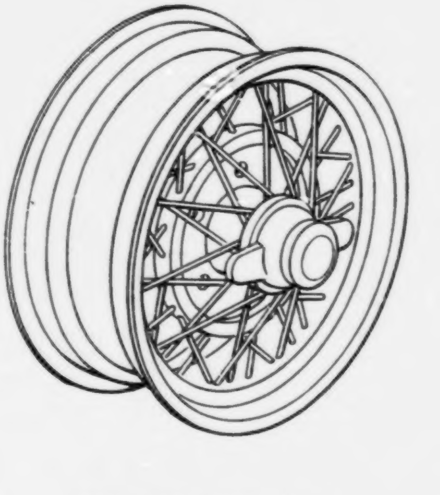


Figure 32-3. Wire Wheel.

TA233933

579

Section II. WHEEL RIMS

32-4. Drop Center. The drop center rim (fig. 32-4) is made in one piece and is fastened to the wheel permanently. Its important feature is a well that permits the mounting and demounting of tires. Bead seats are tapered to match a corresponding taper on the beads of the tire. Drop center rims are used generally on smaller vehicles, such as 1/4-ton 4 x 4 trucks.

32-5. Semidrop Center. The semidrop center rim (fig. 32-5) is also fastened permanently to the wheel. This rim has a shallow-well, tapered-head seat to fit the taper of the beads of the tire. It also has a demountable flange or side ring, which fits into a gutter on the outside edge of the rim, holding the tire in place. This type of rim is standard equipment on 3/4-ton 4 x 4 trucks.

32-6. Safety. Safety rims (fig. 32-6) are similar to drop center rims. The major difference is that safety rims have a slight hump at the edge of the bead ledge that holds the bead in place when the tires go flat. These rims currently are used on many passenger cars and light trucks.

32-7. Split. A split rim (fig. 32-7) is a rim that has a removable bead seat on one side of the rim. The seat is split to allow for its removal so tires can be changed. Some bead seats also require the use of a lockring to retain the seat. These rims are found usually on large vehicles.

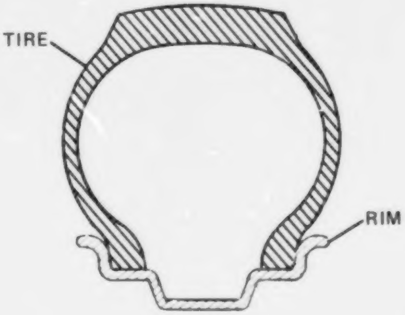


Figure 32-4. Drop Center Rim.

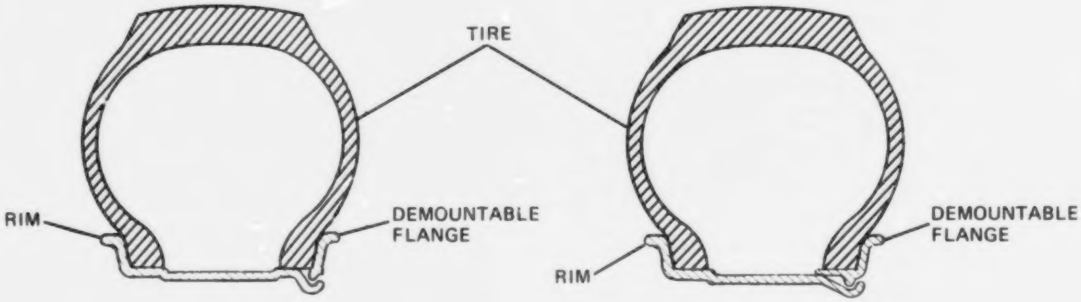


Figure 32-5. Semidrop Center Rim.

TA233820

BEST COPY AVAILABLE

580

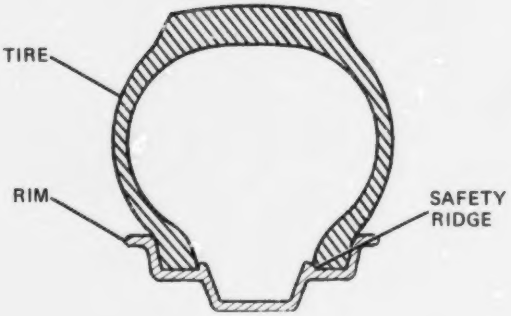

TIRE
RIM
SAFETY
RIDGE

Figure 32-6. Safety Rim.

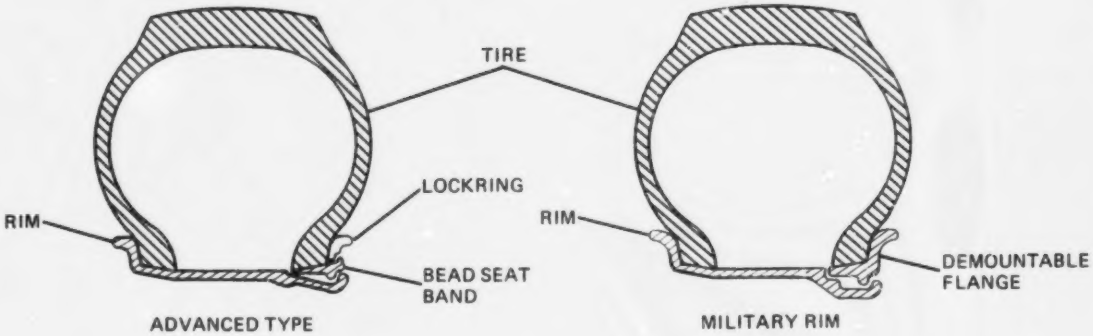

TIRE
RIM
LOCKRING
BEAD SEAT
BAND
ADVANCED TYPE
RIM
DEMOUNTABLE
FLANGE
MILITARY RIM

Figure 32-7. Split Rims.

TA233821

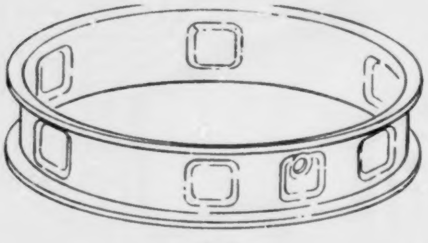
581

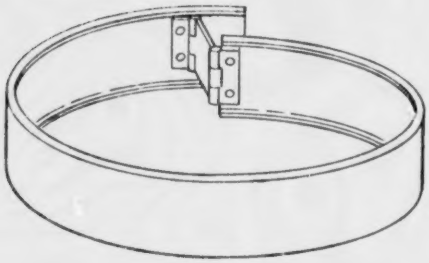
BEST COPY AVAILABLE

Section III. BEAD LOCKS AND BEAD CLIPS

32-8. Bead Locks. A metal device called a bead lock (fig. 32-8) fits between the beads of the tire so that pressure can be applied by tightening the rim flanges against the outside of the bead. The bead lock is slightly wider than the space between the tire beads when mounted on the rim. Thus, a compression fit is obtained that locks the beads in place so they will not slip on the rim and will hold the tire in position. This is necessary in combat to support the load when operating tires without air pressure.

32-9. Bead Clips. Bead clips (fig. 32-9) are used instead of bead locks on certain sizes of tires. Bead clips are used in multiples; five to six clips are spaced equally on each bead of the tire.


CHANNEL


HINGED

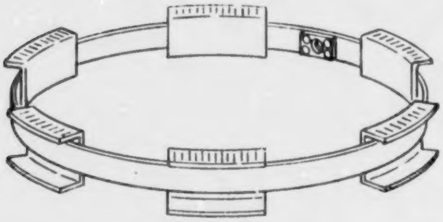

SEGMENTAL

Figure 32-8. Bead Locks.

TA233822

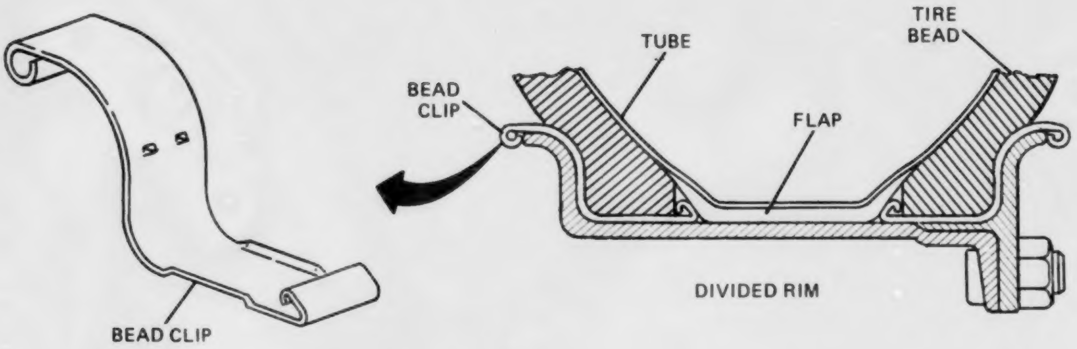


Figure 32-9. Bead Clips.

Section IV. TIRES

32-10. Tire Assembly Construction.

a. Radial. Radial tires (fig. 32-10) are constructed with casing plies perpendicular to the tread direction, with several layers of tread-reinforcing plies (steel or fabric) just under the tread area. This construction permits flexing of the tire with a minimum of tread distortion, better traction, and a softer ride.

b. Bias. Bias-ply tires (fig. 32-11) are constructed of rayon, nylon, or polyester casing plies in a crisscross pattern wrapped around steel bead wires. These bead wires prevent the tire from opening up and separating from the rim at high speeds. The casing plies give the tire its shape. This construction may be found in use today for standard commercial tires.

c. Solid. Solid tires (fig. 32-12) generally are not used in transportation vehicles because of their harsh riding characteristics. They usually do not roll as freely as pneumatic tires and therefore require more power to drive them.

32-11. Types of Tires.

a. Tactical Tires. Tactical tires give good traction in either direction in mud, snow, or on dirt; on temporary roads; and for cross-country use. They also are practical for hard-surface roads. These tires have a nondirectional, mud-and-snow or cross-country tread design with bar-type lugs. A nondirectional tread design indicates the tread pattern is the same, no matter which way the tire is mounted. A nondirectional tread gives good traction in both directions.

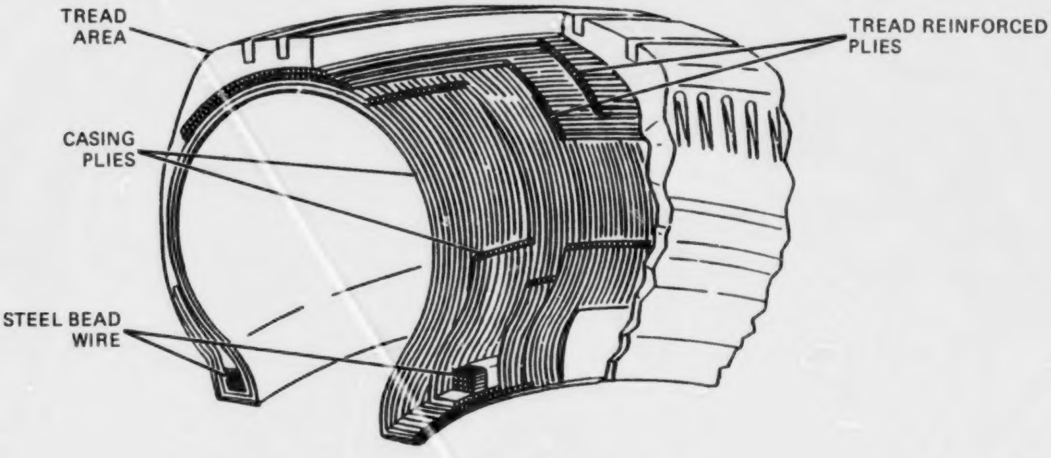


Figure 32-10. Radial Tire Construction.

TA233823

583

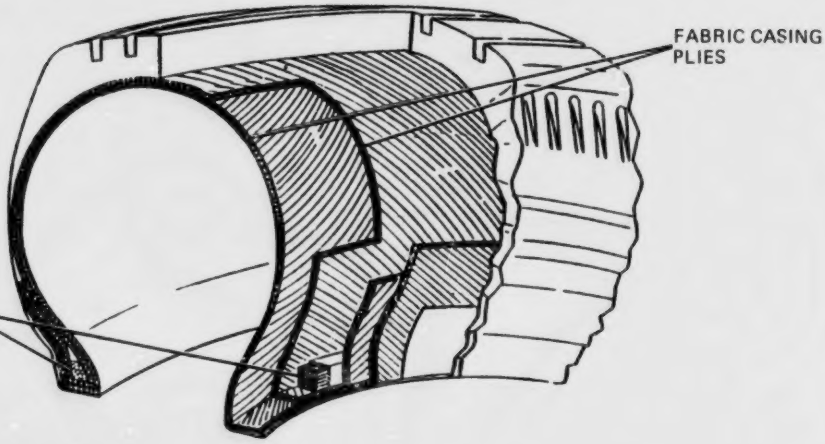


Figure 32-11. Bias-Ply Tire Construction.

b. Combat Tires. Combat tires are made of much heavier construction than commercial-type tires. They have more rigid sidewalls and heavily cushioned plies that are spaced wider apart than the commercial type. They are designed to operate without air pressure for a limited distance when the tactical situation requires it. They have a nondirectional mud-and-snow tread, which provides good traction in either direction on dirt, on temporary roads, and for cross-country use.

c. Truck and Bus Tires. Truck and bus tires are of standard construction like those used on commercial-type vehicles. Regular tread is common on truck and bus tires and will provide satisfactory traction and long life on highways.

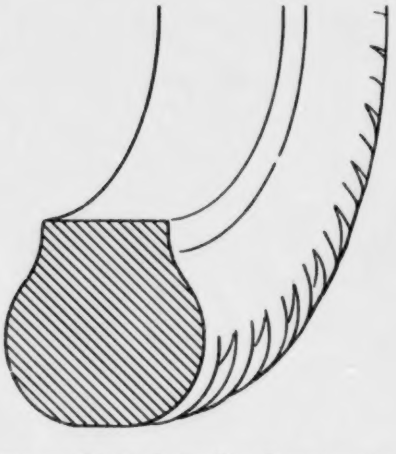


Figure 32-12. Solid Tire Construction.

d. Passenger Tires. Passenger tires are of standard construction and provide good traction on wet and dry roads. In areas where there is snowfall, a nondirectional snow tire sometimes is used on the driving wheels for added traction.

e. Rock-Service Tires. Rock-service tires are large tires of standard construction like those used on commercial-type vehicles for off-road service and on unpaved roads.

f. Earthmover Tires. Earthmover tires are large tires of standard construction like those used on commercial-type vehicles for off-road service. This tread is considered nondirectional. The earthmover tread design also may be directional, similar to tread on grader tires, or nondirectional, similar to tread on rock-service tires.

g. Grader Tires. Grader tires are similar to earthmover tires except that they are designed for lower inflation pressures and for service involving extreme angular ground contact. The directional mud-and-snow tread design provides good traction in mud and snow, on dirt or temporary roads, and for cross-country use.

h. Run Flat Tires. Run flat tires are constructed of a thick sidewall with an air chamber inside the center section of the tire. It is pressurized the same as a standard tire, but if a puncture should occur, the thick sidewalls help support the weight of the vehicle until the repair can be made. This type of tire generally is used on a combat vehicle.

TA233824

32-12. Types of Treads.

a. Mud and Snow (MS) Tread.

(1) *Directional.* The directional mud and snow tread (fig. 32-13) is of a V-design with large spaces between the lugs. The spaces between the lugs are kept free from snow because of tire rotation and flexing, therefore improving traction. A directional tire may be mounted on the rim only one way and will deliver traction in one direction only. The point of the V-design must contact the ground first when traction is required. A directional tread also may be called a traction tread.

(2) *Nondirectional.* The nondirectional mud and snow tread design (fig. 32-14) also has large spaces between the lugs. The lugs are placed perpendicular to the centerline of the tire. This design provides good traction in both directions.

b. Cross-Country Tread. The cross-country tread (fig. 32-15) is the same as the mud and snow tread, except that the cross-country tread has rounded shoulders.

c. Regular Tread. Regular tread (fig. 32-16) consists of small spaces between tread patterns. This allows for a quiet ride and safe operation on wet and dry roads. This tread commonly is used on modern highway-operated tires.

d. Rock Service Tread. Rock service tread (fig. 32-17) is characterized by narrow voids between lugs so that loose rock cannot be caught and tear the tread lugs loose from the tire body. This tread design is used on tires for service on rough terrain and is of the nondirectional type.

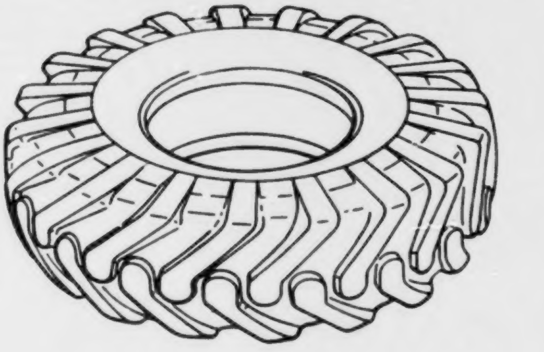


Figure 32-13. Directional Mud and Snow Tread.

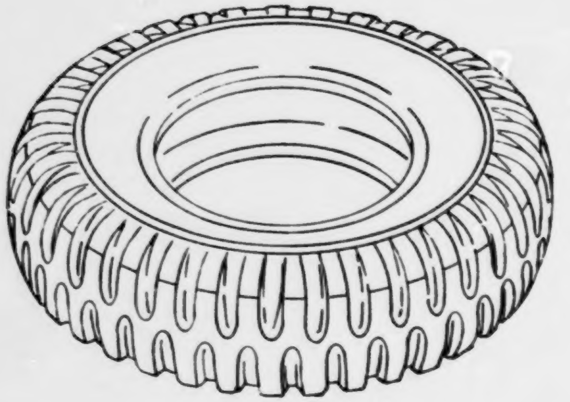


Figure 32-14. Nondirectional Mud and Snow Tread.

e. Earthmover Tread. This tread design (fig. 32-18) may be like either of those used on commercial-type vehicles for off-road service, which are nondirectional or similar to grader tires, which are directional.

f. Traction Tread. Traction tread is similar to the V-design of the mud and snow directional tread. This design provides maximum traction in soft soil.

g. Desert Tread. Desert tread patterns generally are wider than average to distribute the weight of the vehicle over a larger area. The tread pattern may be either directional or nondirec-

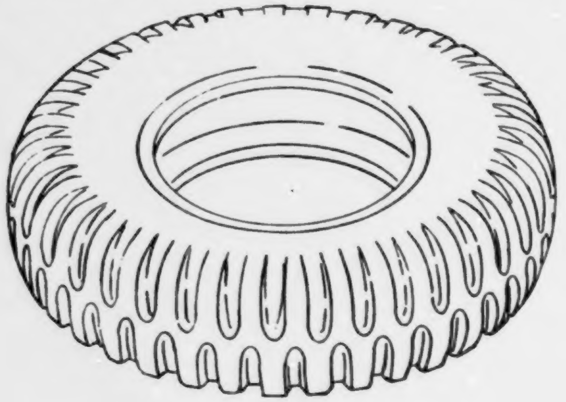


Figure 32-15. Cross-Country Tread.

TA233825

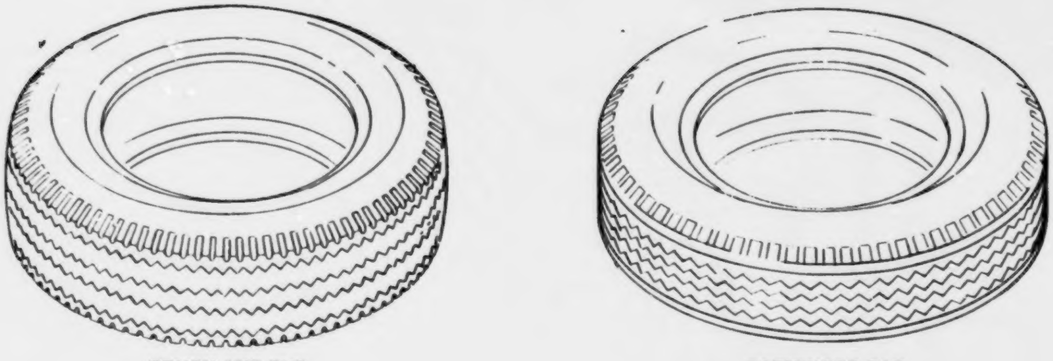


Figure 32-16. Regular Treads.

tional, depending upon the application. Most desert tread patterns are similar to the tactical tire with cross-country tread.

32-13. Ozone-Resistant Rubber. Factors contributing to the deterioration of tires in storage include sunlight, heat, air in motion, ozone, oil, grease, dust, dirt, and water. Ozone is a gas found in the atmosphere and is very harmful to rubber. Military tires are specified to contain certain oils and waxes known as antiozoants, which migrate to the surface of the tire when it is flexed in operation. These substances protect the rubber from ozone. When the tire is in storage, the antiozoants stay inside the tire, causing it to deteriorate.

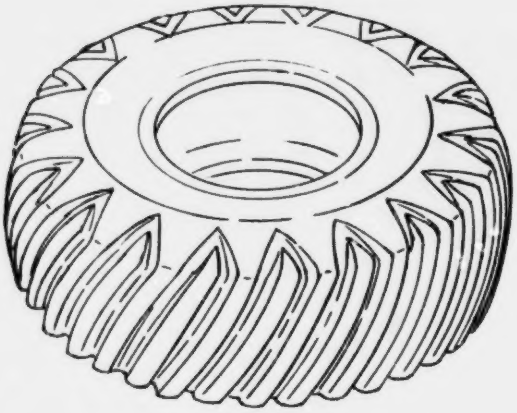


Figure 32-17. Rock Service Tread.

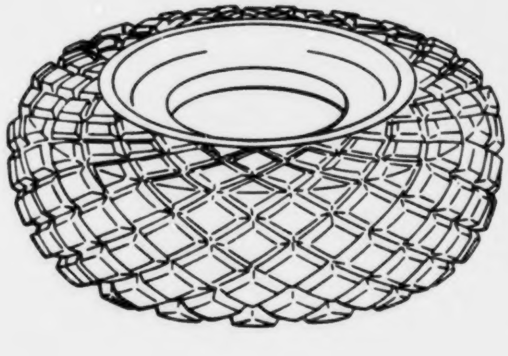


Figure 32-18. Earthmover Tread.

TA233826

586

Section V. TUBES

32-14. Types of Tubes.

a. *Standard.* Standard tubes (fig. 32-19) are circular rubber containers that fit inside the tire and hold the air that supports the vehicle. Though it is strong enough to stand only a few pounds of air pressure when not confined, the tube bears extremely high pressures when enclosed in a tire and wheel assembly. Because the tube is made of comparatively soft rubber to fulfill its function, it is easily chafed, pinched, punctured, or otherwise damaged. Standard tubes generally are made of butyl, a synthetic rubber that has air-retention properties superior to natural rubber. Standard tubes are made of one layer of rubber molded in the shape of a doughnut. They are used regularly for standard tires.

b. *Combat.* Combat tubes (fig. 32-20) are constructed the same as standard tubes except that they are smaller than standard tubes with the same size markings. Because the inside cross section of combat tires is smaller, combat tubes only will be used with combat tires. However, in the event that combat tubes are not available, it is permissible to use the next size smaller standard tube.

c. *Bullet Resisting.* Bullet-resisting tubes (fig. 32-21) are of a heavy, thick construction that automatically seals bullet punctures. Bullet-resisting tubes are identified by their extra weight and thickness and generally have green-painted valve stems.

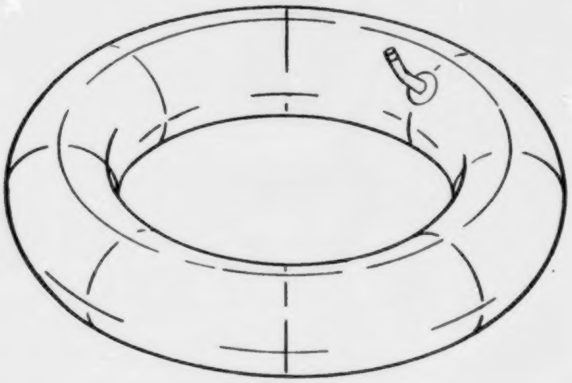


Figure 32-19. Standard Tube.

32-15. Tube Flaps. Tube flaps (fig. 32-22) usually are constructed of a strip of semihard rubber with tapered ends that form a circle. Flaps are required in tube-type tires that are used on flat-base rims. They protect the tube from being pinched between the tire bead and the rim and from irregularities on the base of the rim.

32-16. Types of Valves.

a. *Cured-On Valve.*

(1) *Rubber-Covered Valve.* Cured-on valve stems (fig. 32-23) have a rubber base that is vulcanized on the outer surface of the tube and cannot be removed unless it is cut off for replacement. The rubber-covered stem is bendable when the stem is longer than 3 inches.

(2) *All-Metal-Stem Cured-On Valve.* This valve (fig. 32-24) is mounted to the tube the same way as the rubber-covered valve, but this type uses a nonbendable, all metal stem.

b. *Cured-On Large-Bore Valve.* Cured-on large-bore valve stems generally are used on tubes for very large tires such as for earthmovers. The large bore permits rapid inflation and deflation of tubes. Except for size, they are similar to the cured-on valve described above.

c. *Cured-In Valve.* Cured-in valve stems (fig. 32-25) are similar to cured-on valve stems except that the rubber base is inverted and vulcanized to the inner surface of the tube. The rubber base also may be vulcanized directly to the rubber body of the tube.

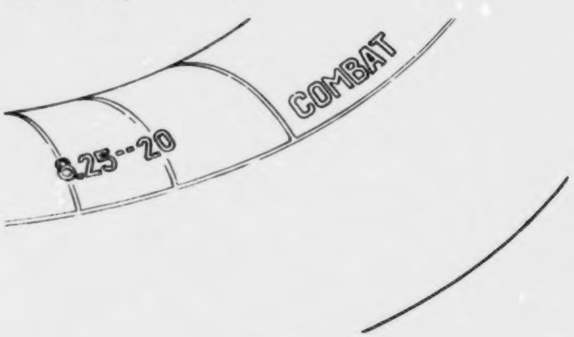


Figure 32-20. Combat Tubes. TA233827

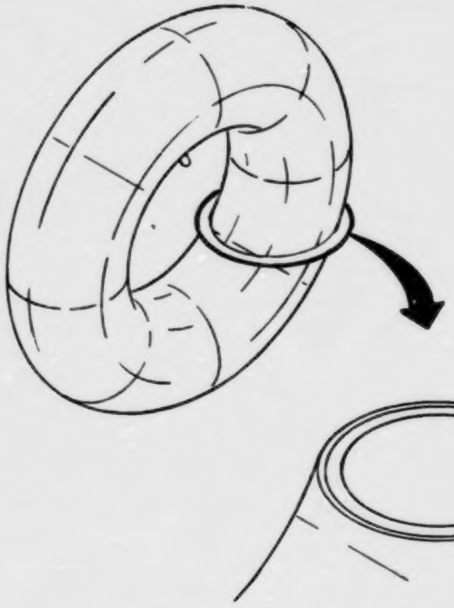


Figure 32-21. Bullet-Resisting Tube.

d. Spud-Mounted Valve. Spud-mounted valves (fig. 32-26) are constructed in two parts for attaching to the tube. These valves are airtight at the base because of the clamping action between the spud and stem base. They are identified readily by the absence of a bridge washer and hex nut. The eger spud valve no longer is used, but the principle of two-part construction has been continued by some manufacturers. The eger spud has been replaced by a cured-in spud, whose outside thread accepts a valve stem replacement with a preformed packing.

e. Snap-In Tubeless Tire Valve. Snap-in tubeless tire valve stems (fig. 32-27) are used with many passenger car and light truck tires. This type of valve stem is mounted on tubeless tire rims through a circular hole of controlled dimension. The valve stem is encased in a heavy, pear-shaped, rubber cover. The base of the valve is shaped like a mushroom head and below the threaded shank there is a slight ridge. When the valve is installed properly, the edge of the rim valve hole will be between the mushroom head and the ridge, forming an airtight seal.

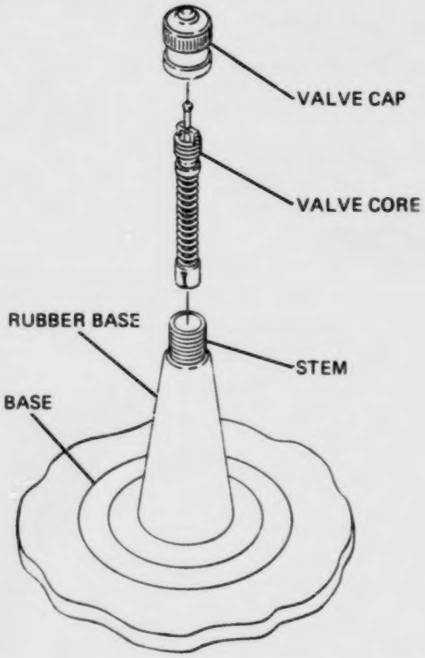


Figure 32-23. Cured-On Rubber-Covered Valve.

f. Clamp-In Tubeless Tire Valve. Clamp-in tubeless tire valve stems are used with passenger

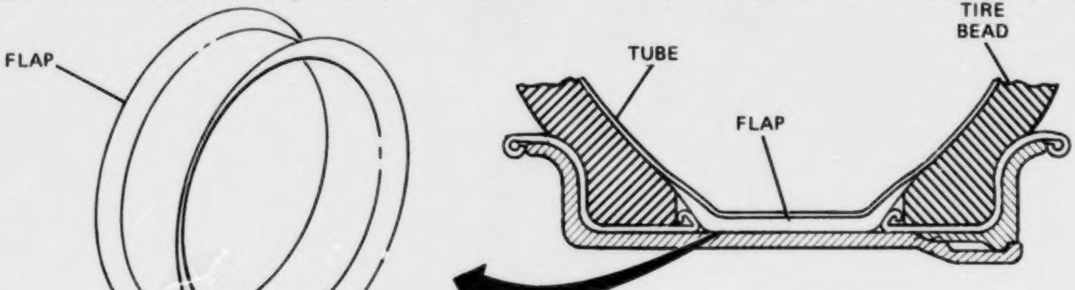


Figure 32-22. Tube Flaps.

TA233828

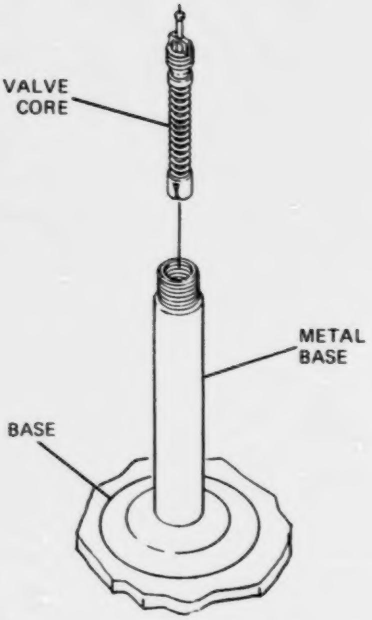


Figure 32-24. All-Metal-Stem Cured-On Valve.

car and light truck tubeless tires. This valve stem is mounted on tubeless tire rims through a circular hole of a controlled dimension. The valve is airtight at the base because of the clamping action of the ring washer and the hex nut.

g. Clamp-In, Large-Bore Tubeless Tire Valve. Clamp-in, large-bore tubeless valve stems are available in three types: straight-type, swivel-type, and nonswivel-type valves. Large-bore valves are used on rims for very large earthmover tires. They permit rapid inflation and deflation of tires. An airtight seal is formed by the rubber washer when the mounting hex nut is tightened.

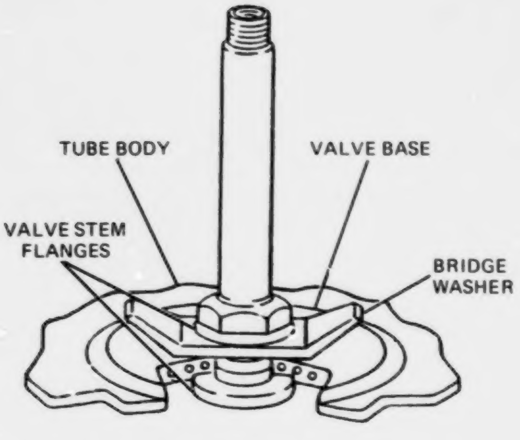


Figure 32-25. Cured-In Valve.

h. Clamp-In, Double-Bent Tubeless Tire Valve. Clamp-in, double-bent tubeless valve stems have an extra low vertical height. They are attached to the rim by tightening the hex nut against the rim. This ensures an airtight seal at the base of the valve.

32-17. Valve Accessories.

a. Valve Core. The valve core (fig. 32-28) is that part of the valve that is screwed into the valve stem and permits air, under pressure, to enter, but prevents it from escaping. There are two types of valve cores and two sizes of each type. The two types are the visible spring type and concealed spring type. The two types are interchangeable. Two sizes are provided for the standard bore and the large bore valve stems. The core shell has a rubber washer that provides an airtight seal against the tapered seat inside the stem. Directly below the shell is a cup that contains a rubber

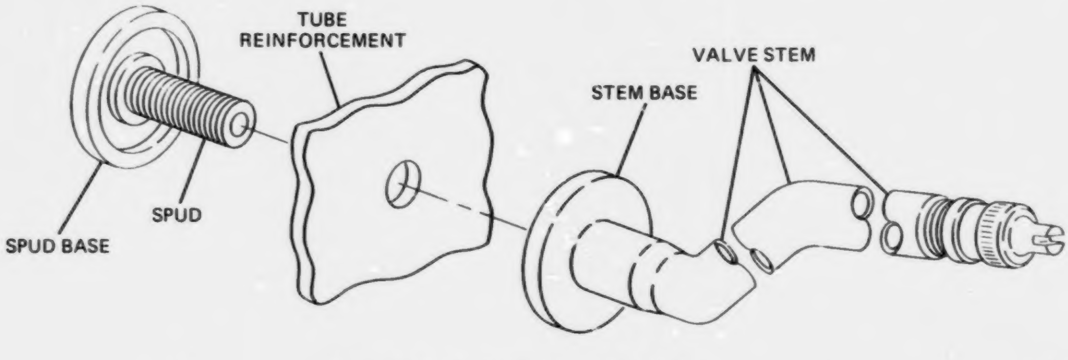


Figure 32-26. Spud-Mounted Valve.

TA233829

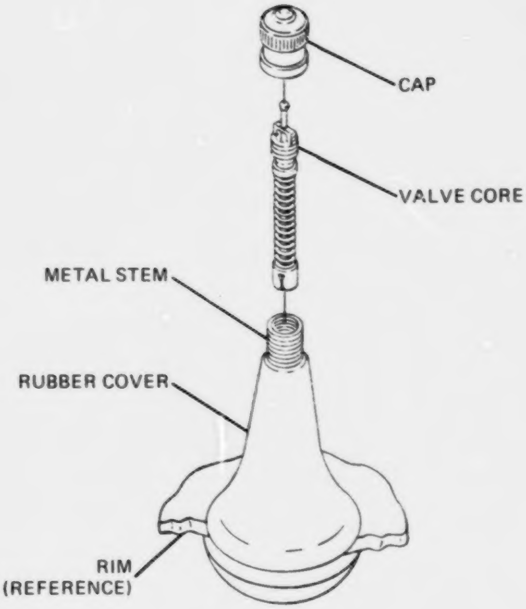

CAP
VALVE CORE
METAL STEM
RUBBER COVER
RIM
(REFERENCE)

Figure 32-27. Snap-In Tubeless Tire Valve.

seat, which, in the closed position, is forced against the bottom of the shell, forming an airtight seal. The pin on top of the valve core, when pushed down, forces the cup away from the shell, permitting air to flow.

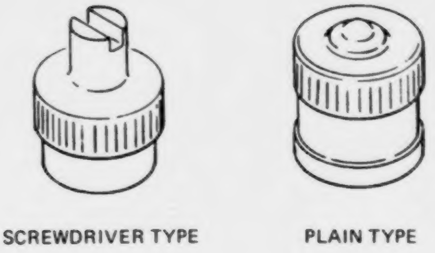

SCREWDRIVER TYPE
PLAIN TYPE

Figure 32-29. Valve Caps.

b. Valve Caps. The valve cap (fig. 32-29) is also a component part of the valve and is screwed onto the end of the stem, providing a second airtight seal. The cap also protects the threads on the end of the stem and keeps dirt and moisture out of the valve body. The screwdriver-type cap has a forked tip that may be used to install or remove the valve core. The plain cap generally is used on rubber-covered valves and has a skirt that contacts the rubber covering on the valve stem. Screwdriver and plain-type caps are interchangeable with each other.

32-18. Identification of Tires and Tubes. All tire identification markings and codes generally are in raised letters and numbers on the sidewall of the tire. Combat tires are marked COMBAT on the serial number side. Tubes for combat tires also are stamped COMBAT. See paragraph 32-14c for identifying features of bullet-resisting tubes.

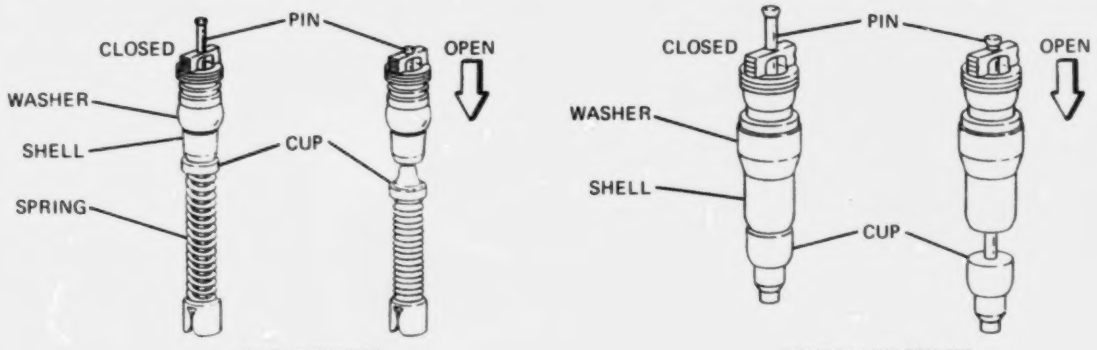

CLOSED
PIN
OPEN
WASHER
SHELL
CUP
SPRING
VISIBLE SPRING
CLOSED
PIN
OPEN
WASHER
SHELL
CUP
CONCEALED SPRING

Figure 32-28. Valve Cores.

TA233830

590

Section VI. TRACKS

32-19. Track Characteristics. The track is a circular flat-band assembly that is mounted under the road wheels and driven by sprockets in the rear of the vehicle. The track is designed to distribute the weight of the vehicle over a large area so that the vehicle will not sink on soft surfaces. The assembly also is able to bridge large gaps in terrain that would render a wheeled vehicle immobile.

32-20. Sectional Band Tracks. Sectional band tracks (fig. 32-30) are designed so that sections of this type track are replaced when worn or damaged, rather than replacing the whole track assembly. In this design, parallel cable reinforced bands are clamped between the cover plates and track bars by means of through bolts and self-locking nuts. Each track section is made to a convenient length for ease of handling and is connected to adjacent sections by connector plates. The joint is made between the track bars. However, some designs provide for the joint to be made at the track bar.

32-21. Pin Connected Tracks.

a. Double-Pin Tracks. Double-pin tracks (fig. 32-31) consist of a pair of track blocks assembled onto two rubber-bushed pins. The blocks are linked together by the end connectors, which engage the track pins. The end connectors are secured to the pins by means of wedges and wedge nuts.

b. Single-Pin Tracks. Except for the single-pin arrangement, the general design features are similar to the double-pin track links. Component nomenclature is somewhat different in that the single-pin track (fig. 32-32) has no blocks. The basic metal and rubber structure is called the body. The addition of the bushings completes the link, which is comparable to the link of the double-pin track. The link, pin, nuts, and washers make up the shoe assembly.

32-22. Shoe Types.

a. Integral Center Guide. An integral center or track guide (fig. 32-32) is cast into the track shoe itself. It engages the road wheel so that the alinement of the track is maintained and also absorbs lateral forces caused by steering and side slope conditions.

b. Detachable Center Guide. The detachable center guide (fig. 32-31) serves the same function as the integral center guide but is detachable from the shoe.

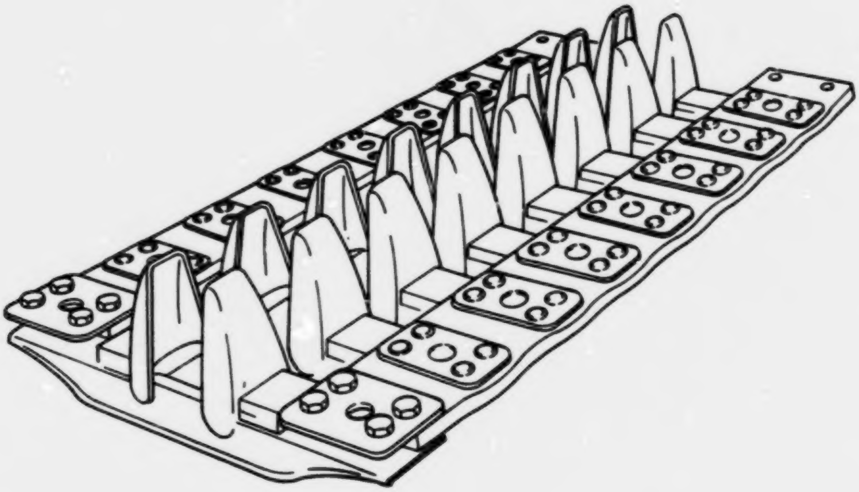


Figure 32-30. Sectional Band Tracks.

TA233831

591

BEST COPY AVAILABLE

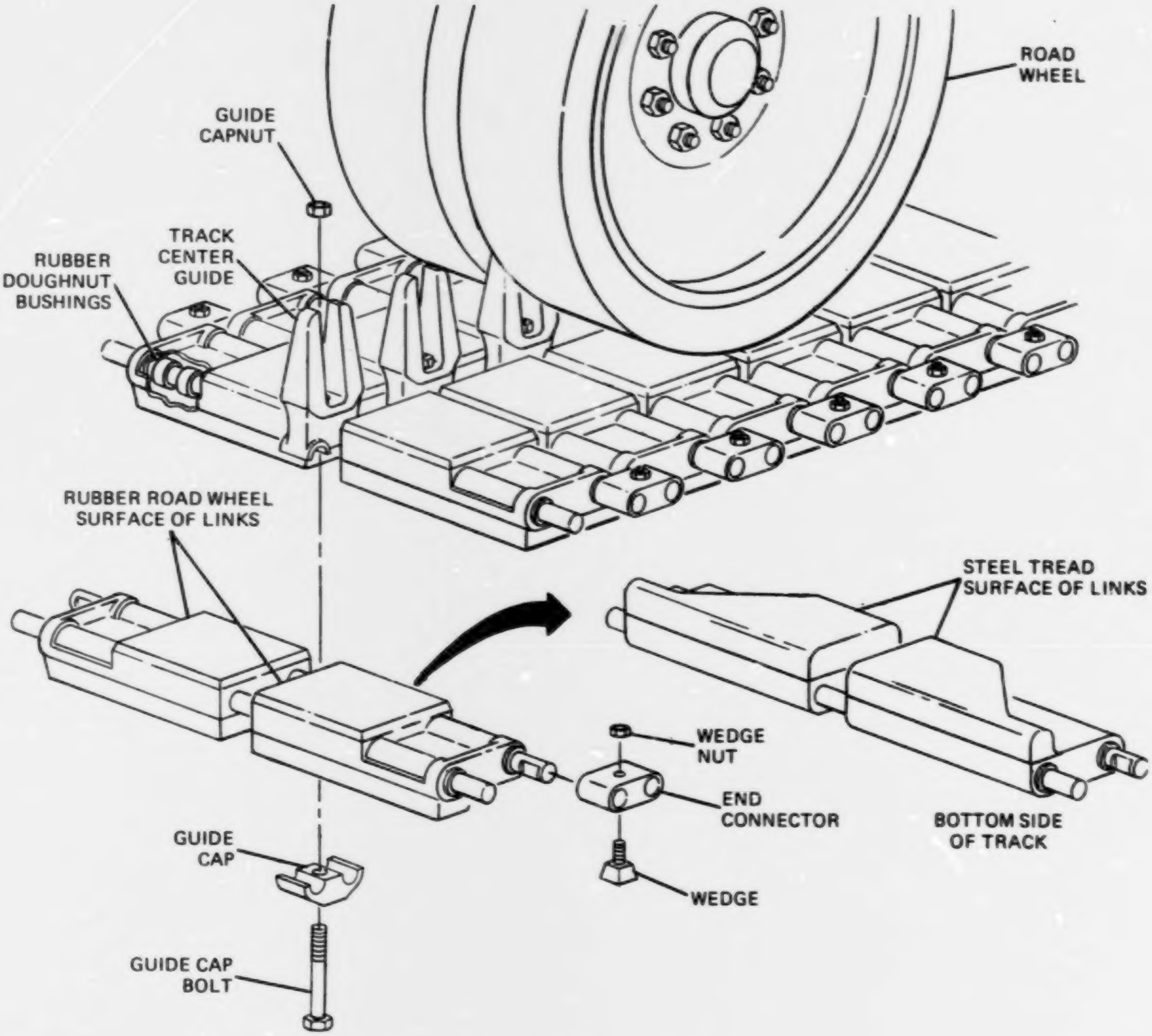

GUIDE CAPNUT
ROAD WHEEL
TRACK CENTER GUIDE
RUBBER DOUGHNUT BUSHINGS
RUBBER ROAD WHEEL SURFACE OF LINKS
STEEL TREAD SURFACE OF LINKS
WEDGE NUT
END CONNECTOR
BOTTOM SIDE OF TRACK
GUIDE CAP
WEDGE
GUIDE CAP BOLT

Figure 32-31. Double-Pin Tracks.

32-23. Pad Types.

a. Integral Rubber Pad. Integral rubber pads frequently are placed on the ground-engaging surface of the track to cushion the interaction of the track with the ground and improve traction on hard surfaces. The integral rubber pad is vulcanized permanently or cemented to the track shoe assembly, and when worn out, must be replaced as a unit.

b. Detachable Rubber Pad. This type of pad (fig. 32-32) serves the same purpose as the integral pad but is detachable from the shoe.

TA233832

592

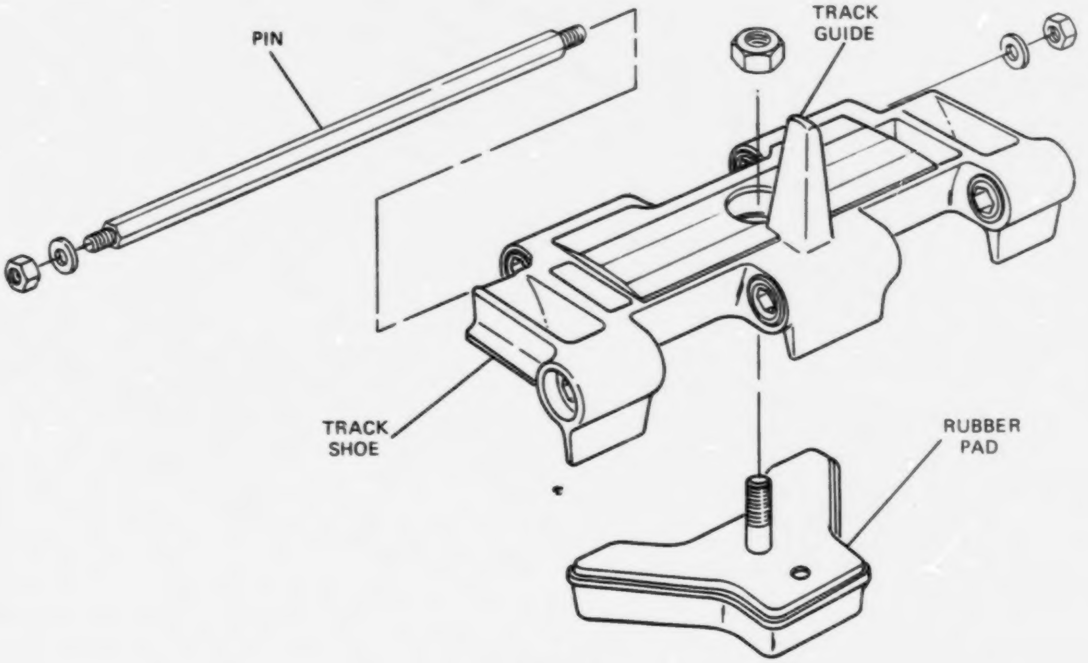

PIN
TRACK GUIDE
TRACK SHOE
RUBBER PAD

Figure 32-32. Single-Pin Tracks.

TA233833

593

CHAPTER 33

STEERING SYSTEMS AND WHEEL ALINEMENT

Section I. STEERING SYSTEMS

33-1. Steering Methods.

a. Ackerman System. The ackerman system (fig. 33-1) is used exclusively on passenger cars and many wheeled military vehicles. Correct ackerman steering during a turn requires that each wheel turn around a point located on an extension of the rear axle centerline. The steering arms are bent slightly toward each other so that their centerlines, if extended, would intersect in front of the rear axle. With the ackerman system, as the vehicle is making a turn, the inside wheel will turn sharper than the outer wheel, therefore allowing all the wheels to travel around a common point.

b. Fifth Wheel. Fifth-wheel steering (fig. 33-2) is accomplished by pivoting an entire axle around a central point. The wheels of each axle maintain their initial position with respect to each other and the interconnecting axle during a turn. This type of steering commonly is applied to towed vehicles because of the mechanical difficulties of controlled steering and because greater underbody clearance is required for fifth-wheel steering systems.

33-2. Solid Axle Steering Linkage. The steering linkage on vehicles with a solid front suspension (fig. 33-3) only needs to deal with the relative motion between the front axle and frame. For this reason the steering linkage is fairly simple and easily designed.

a. The common solid axle suspension utilizes a drag link to connect the pitman arm to the steering linkage. The drag link is made in a tubular or rod form and is provided with springs to cushion shocks and prevent transmission of the shocks to the steering gear. A housing is provided on one end of the drag link to receive the ball end of the pitman arm. Ball sockets, coil springs, spring seats, and a screw plug secured by a cotter pin are inserted in this housing to hold the pitman arm ball. Sometimes the slot in which the pitman arm is inserted extends the entire length of the

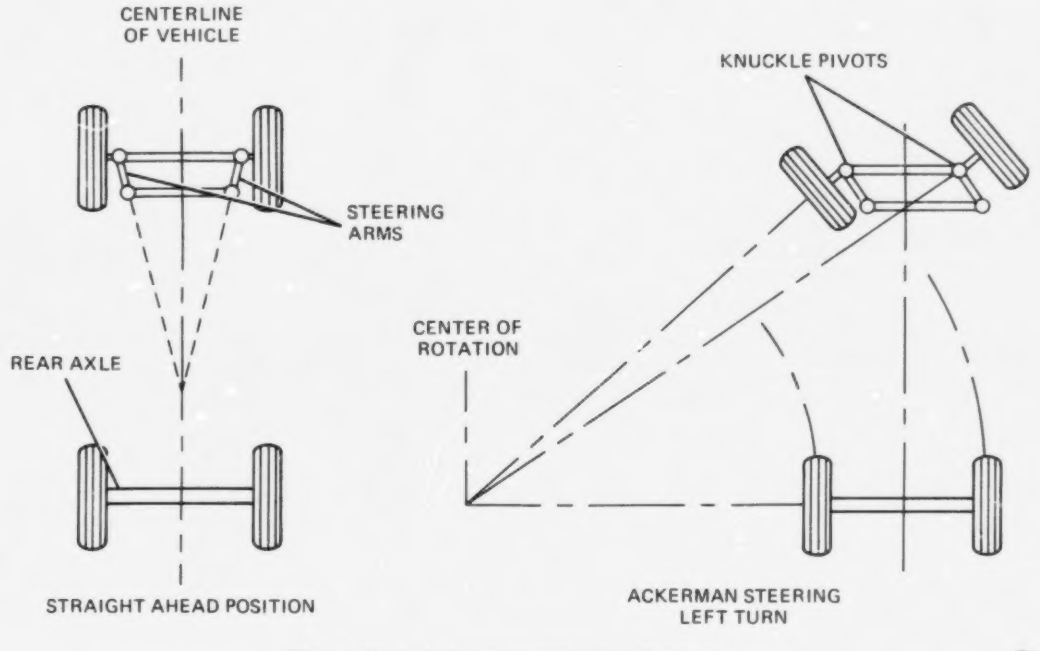
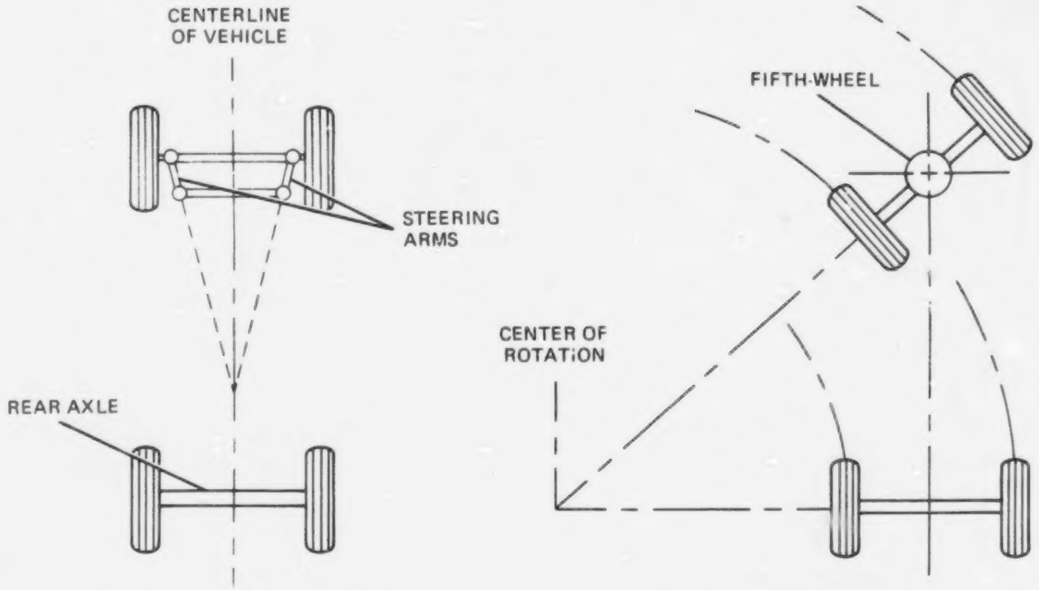


Figure 33-1. Ackerman Steering System.

TA233834

594



STRAIGHT AHEAD POSITION

FIFTH-WHEEL STEERING

Figure 33-2. Fifth-Wheel Steering.

housing, in which case the end of the housing has a screwcap. The end of the drag link connected to the steering knuckle arm is usually somewhat similar though it may be like a tie rod end. Lubrication fittings are provided for each joint. Dust shields are fitted over the ball and socket joints to hold the lubricant and to prevent dust from entering the joint.

b. Steering Arms. The steering arms on the solid axle suspension, like all others, are bent toward each other to achieve toe out on turns. The left side arm is shaped like a bellcrank and accepts the drag link and tie rod.

c. Tie Rod. The tie rod connects the steering arms together and may be located in front of or behind the centerline of the wheel. The tie rod is usually of a solid rod construction but tubular designs also are used.

d. Tie Rod Ends. Tie rod ends are used to form a flexible link between the tie rod and steering arm. The tie rod end usually is fastened to the knuckle arm with a tapered stud. A socket is provided within the tie rod end to hold the end of the stud, which is in the form of a ball or yoke. The socket also allows movement between the knuckle arm and the tie rod. A lubrication fitting usually is provided to keep the ball and socket joint properly lubricated. A dust seal covers the tie rod end to prevent dust from entering the joint and to prevent the loss of lubricant. In the solid axle configuration, the tie rod end is screwed onto the tie rod and is secured with clamps.

33-3. Independent Suspension Steering Linkage. The steering linkage on vehicles with independent suspension must be flexible due to the relative motion of each wheel. To accomplish this, the tie rod must be of a multipiece design. Of the many designs in use, the following are the most common.

a. Center Steering Linkage (Fig. 33-4). One configuration that was used on earlier models utilized two separate tie rods to connect the steering arms together. These tie rods were joined in the middle by an intermediate knuckle arm, which pivoted on the frame. Tie rod ends, described in paragraph 33-2d, are used to form the flexible link to the steering arms.

b. Parallelogram Steering Linkage (Fig. 33-5). This configuration is a very popular steering system for independent front suspension and is used on many of today's vehicles.

TA233835

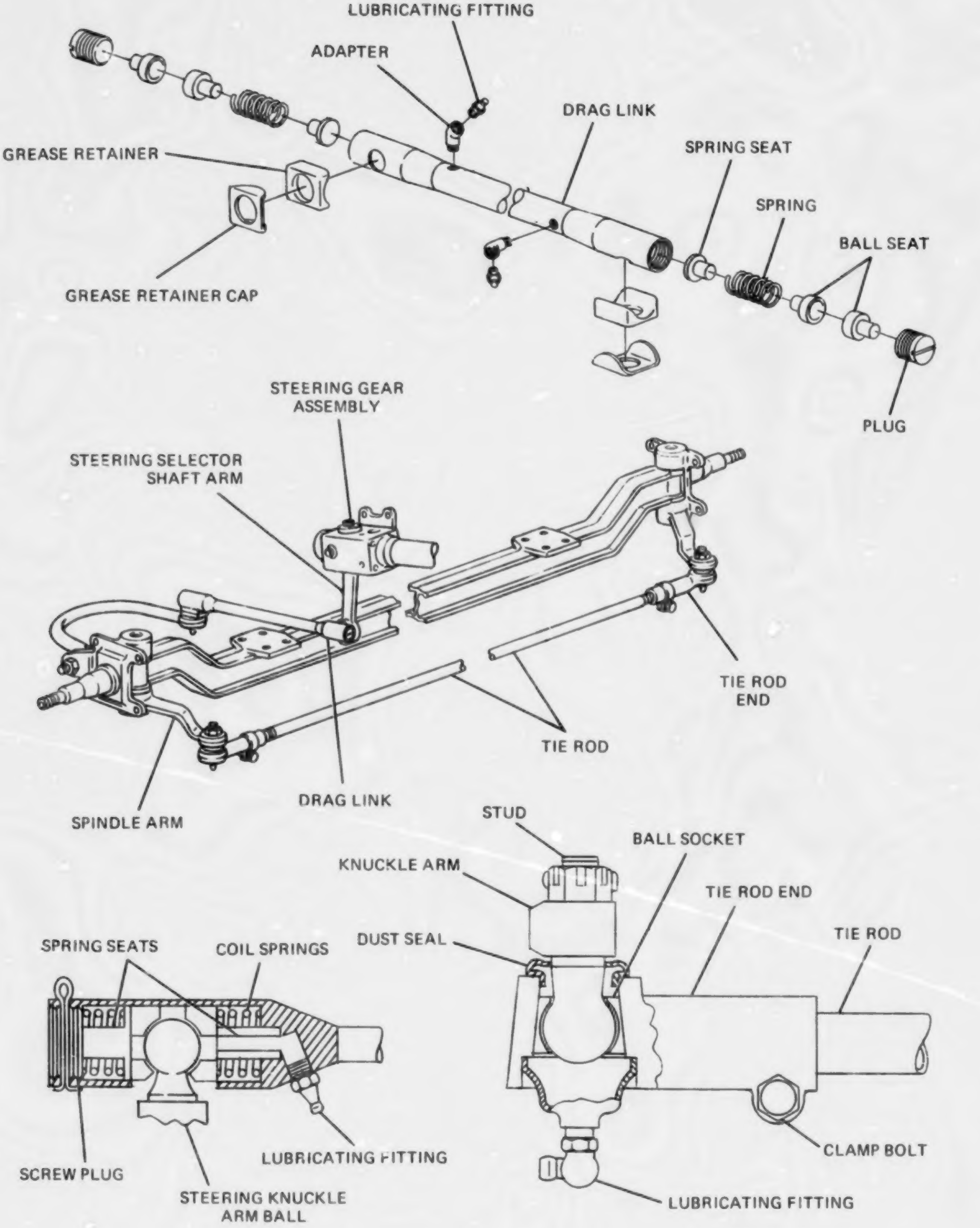

LUBRICATING FITTING
ADAPTER
DRAG LINK
GREASE RETAINER
SPRING SEAT
SPRING
BALL SEAT
GREASE RETAINER CAP
PLUG
STEERING GEAR ASSEMBLY
STEERING SELECTOR SHAFT ARM
TIE ROD END
TIE ROD
DRAG LINK
SPINDLE ARM
STUD
BALL SOCKET
KNUCKLE ARM
TIE ROD END
TIE ROD
DUST SEAL
SPRING SEATS
COIL SPRINGS
CLAMP BOLT
LUBRICATING FITTING
SCREW PLUG
STEERING KNUCKLE ARM BALL
LUBRICATING FITTING

Figure 33-3. Solid Axle Suspension.

TA233836

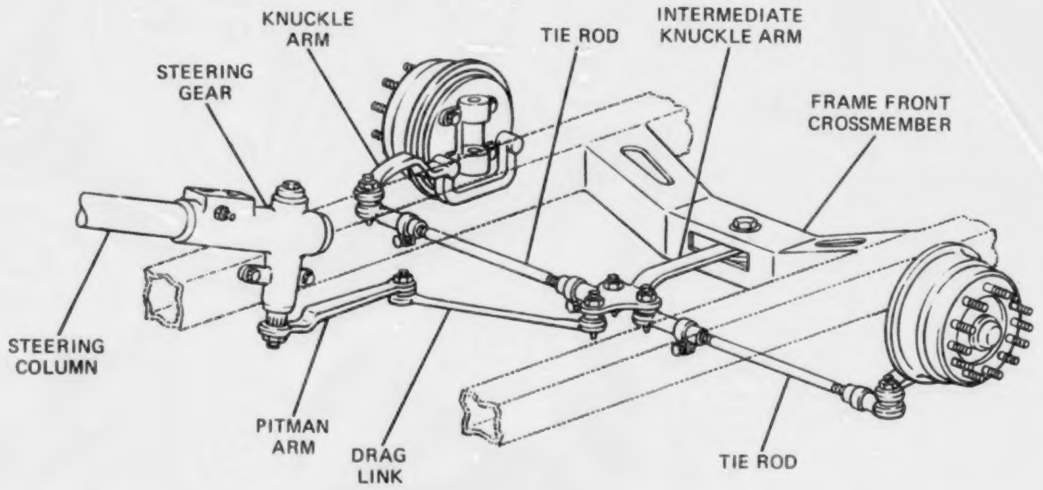

KNUCKLE ARM
TIE ROD
INTERMEDIATE KNUCKLE ARM
STEERING GEAR
FRAME FRONT CROSSMEMBER
STEERING COLUMN
PITMAN ARM
DRAG LINK
TIE ROD

Figure 33-4. Center Steering Linkage.

(1) *Centerlink.* The parallelogram steering system uses a centerlink, otherwise known as an intermediate rod or track rod, to connect the steering arms together. The turning action of the steering box is transmitted to the centerlink through the pitman arm. The pitman arm also provides support for the centerlink. The two components are connected by a hinge or ball joint.

(2) *Idler Arm.* The centerlink is hinged on the opposite end of the pitman arm by means of an idler arm. The idler arm supports the free end of the centerlink and allows it to move left and right with ease.

(3) *Tie Rods.* The tie rod ends in this configuration serve the same purpose as those

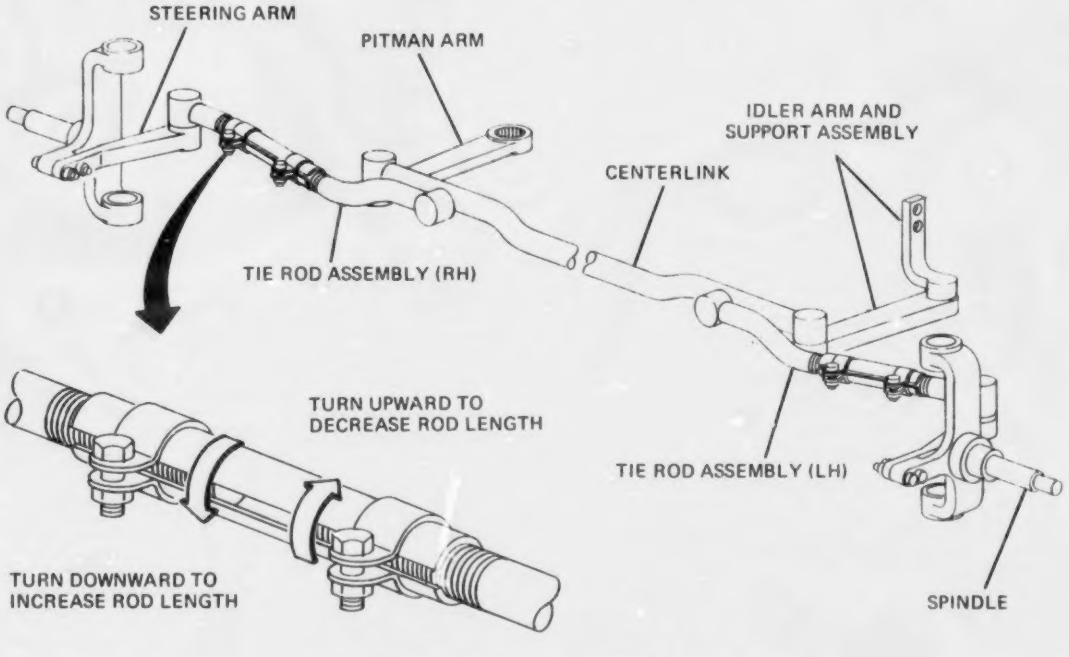

STEERING ARM
PITMAN ARM
IDLER ARM AND SUPPORT ASSEMBLY
CENTERLINK
TIE ROD ASSEMBLY (RH)
TURN UPWARD TO DECREASE ROD LENGTH
TIE ROD ASSEMBLY (LH)
TURN DOWNWARD TO INCREASE ROD LENGTH
SPINDLE

Figure 33-5. Parallelogram Steering Linkage.

TA233837

discussed in paragraph 33-2d but are constructed slightly different. The tie rod ends have a cast housing incorporating a threaded shaft in the design. The tie rods provide a swivel connection to both steering arms and both connections to the centerlink.

(4) *Adjusting Sleeves.* The inner and outer tie rods are connected by adjusting sleeves. These are tubular in design and threaded over the inner and outer tie rods. The adjusting sleeves provide a location for toe adjustment. Clamps and clamp bolts are used to secure the sleeves. Some manufacturers require the clamps be placed in a certain position in relation to the tie rod top or front surface to prevent interference with other parts.

c. Rack and Pinion Steering Linkage (Fig. 33-6). The rack and pinion steering linkage is the simplest form of steering linkage. A ball socket joint, which has a hollow threaded shaft, is generally used to connect the tie rod assembly to the rack and pinion steering gear. The threaded end of the socket assembly accepts the tie rod and allows for toe adjustment. Clamps also are used to secure the tie rod and socket joint. This type of steering linkage is found on many smaller cars.

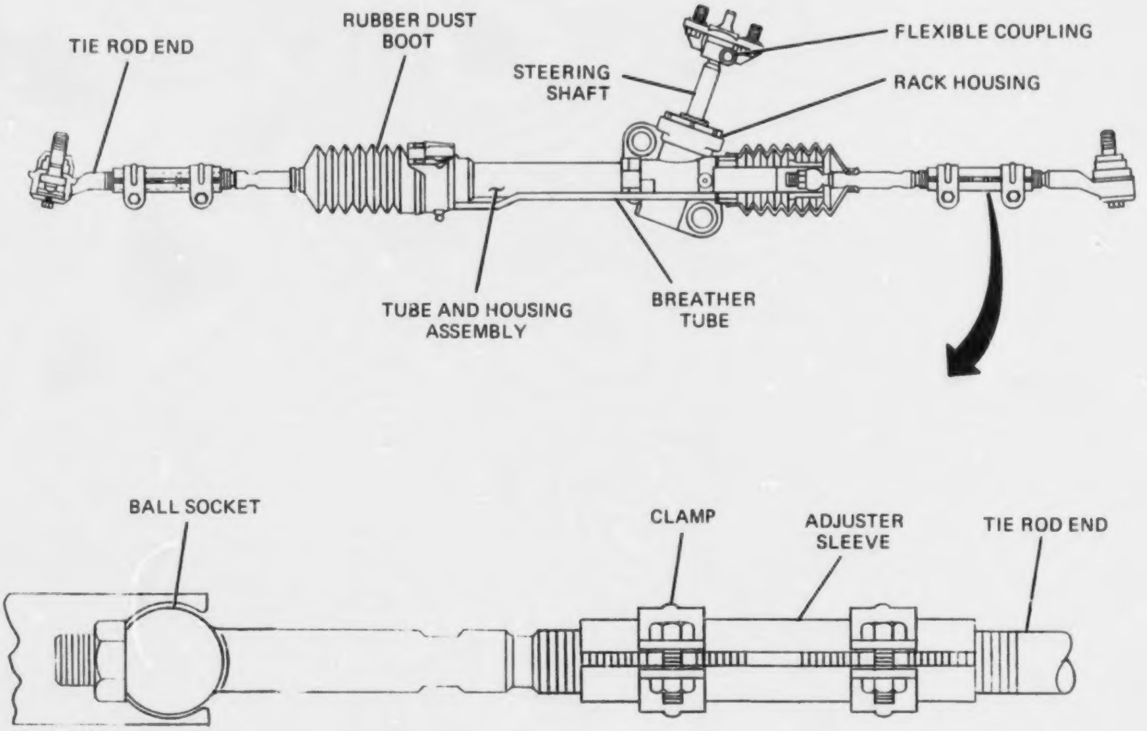

TIE ROD END
RUBBER DUST BOOT
STEERING SHAFT
FLEXIBLE COUPLING
RACK HOUSING
TUBE AND HOUSING ASSEMBLY
BREATHER TUBE
BALL SOCKET
CLAMP
ADJUSTER SLEEVE
TIE ROD END

Figure 33-6. Rack and Pinion Steering Linkage.

TA233838

Section II. STEERING GEARS

33-4. Worm and Sector Type. In the worm and sector steering gear (fig. 33-7) the pitman arm shaft carries a gear that meshes with the worm on the steering gear shaft. Generally, only a sector of a gear is used because it turns through an arc of approximately 70 degrees. The steering wheel turns the worm on the lower end of the steering gear shaft, which rotates the sector and the pitman arm through the use of the shaft. The worm is assembled between tapered roller bearings that take both thrust and load. An adjusting nut or plug is provided for adjusting the end play of the worm. Some means of adjusting the end play of the cross-shaft also is provided.

33-5. Worm and Roller Type. The worm and roller steering gear (fig. 33-8) is quite similar to the worm and sector type except that a roller is supported by ball or roller bearings within the sector mounted on the pitman arm shaft. These bearings assist in reducing sliding friction between the worm and sector. As the steering wheel turns the worm, the roller turns with it but forces the sector and the pitman arm shaft to rotate. The hourglass form of worm, which tapers from both ends to the center, affords better contact between the worm and roller at all positions. It provides a variable ratio to permit faster and more efficient steering. Variable ratio means that the ratio is larger at one position than another and therefore the road wheels are turned faster at certain positions than at others. At the center or straight ahead position, the steering gear ratio is high, giving more steering control. However, as the wheels are cramped or turned to the side, the ratio decreases so that the action is much more rapid. This design is very helpful for parking or for maneuvering the vehicle.

33-6. Cam and Lever Type. A cam and lever steering gear in which the worm is known as a cam, is shown in figure 33-9. The pitman arm shaft carries a lever on the inner end. This lever carries a stud that engages with the cam. The stud may be integral or mounted on roller bearings. Roller bearings reduce friction and allow easier steering. As the steering wheel is turned, the stud moves up and down on the cam and carries the lever with it to rotate the pitman arm shaft. The pitch of the cam is not constant, therefore the lever moves more rapidly as it nears either end of the cam. Maximum leverage occurs at the straight ahead position when the stud engages the fine pitch section of the cam. This makes the initial turning of the wheels easier. Therefore, a variable ratio is obtained with cam and lever steering. A twin lever provided with two studs (fig. 33-9) is used on a design for heavier vehicles

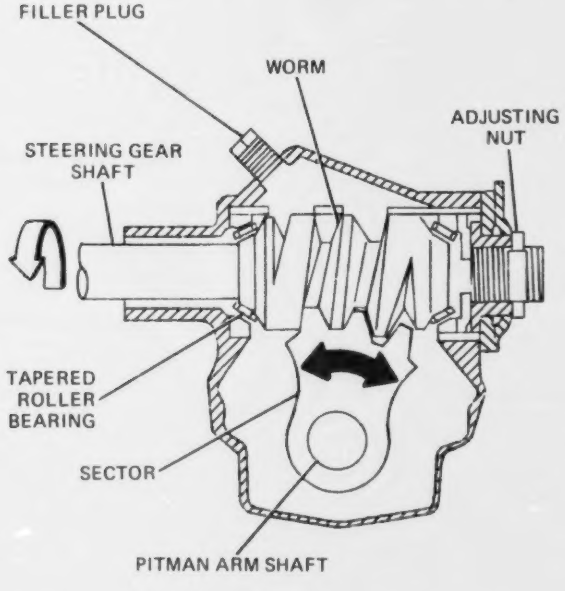


Figure 33-7. Worm and Sector Steering Gear.

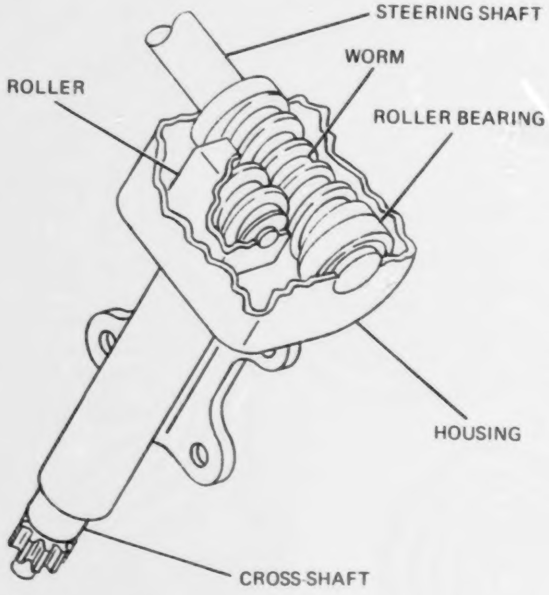


Figure 33-8. Worm and Roller Steering Gear.

TA233839

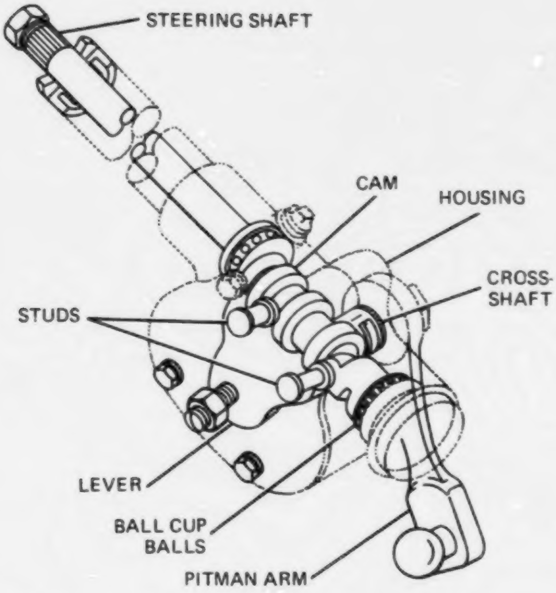

STEERING SHAFT
CAM
HOUSING
CROSS-SHAFT
STUDS
LEVER
BALL CUP BALLS
PITMAN ARM

Figure 33-9. Cam and Lever Steering Gear.

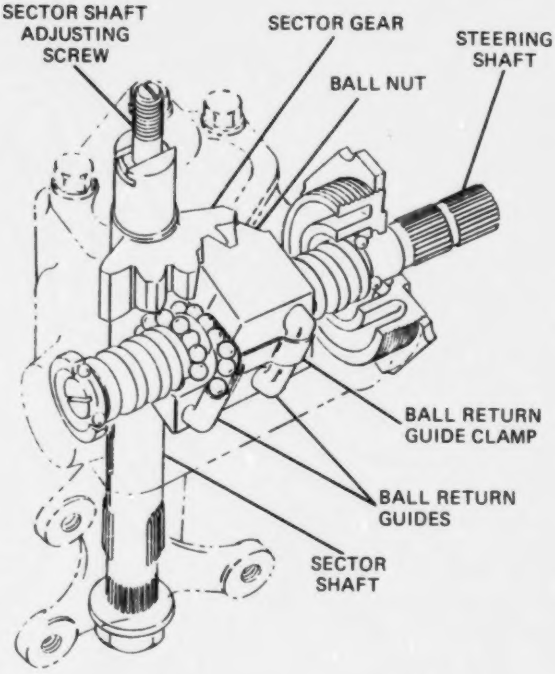

SECTOR SHAFT ADJUSTING SCREW
SECTOR GEAR
STEERING SHAFT
BALL NUT
BALL RETURN GUIDE CLAMP
BALL RETURN GUIDES
SECTOR SHAFT

Figure 33-10. Worm and Nut Steering Gear.

because of its added strength and steering stability.

33-7. Worm and Nut Type. Another form of steering gear is the worm and nut, which is made in several different combinations. A nut is meshed with the worm and screws up and down on it. The nut may operate the pitman arm directly through a lever, or through a sector on the pitman arm shaft. An example of the recirculating ball type of the worm and nut steering gear is shown in figure 33-10. In this steering gear, the nut, which is in the form of a sleeve block, is mounted on a continuous row of balls on the worm to reduce friction. This ball nut is fitted with tubular ball guides to return the balls diagonally across the nut to recirculate them as the nut moves up and down on the worm. With this design, the nut is moved on the worm by rolling instead of by sliding contact. Turning the worm moves the nut and forces the sector and the pitman arm shaft to turn.

33-8. Rack and Pinion Type. In the rack and pinion steering system (fig. 33-11) the steering gear shaft utilizes a pinion gear on the end, to mesh with a long rack. The rack is connected to the steering arms by tie rods, which are adjustable, to maintain proper toe angle. As the steering wheel is rotated, the pinion gear on the end of the steering shaft rotates. The pinion moves the rack left and right to operate the steering linkage (para 33-3c). Rack and pinion gears are used on small passenger vehicles where a high degree of precision steering is required. Their use on larger vehicles is limited because of the conflicting space requirements of rack and engine.

TA233840

600

BEST COPY AVAILABLE

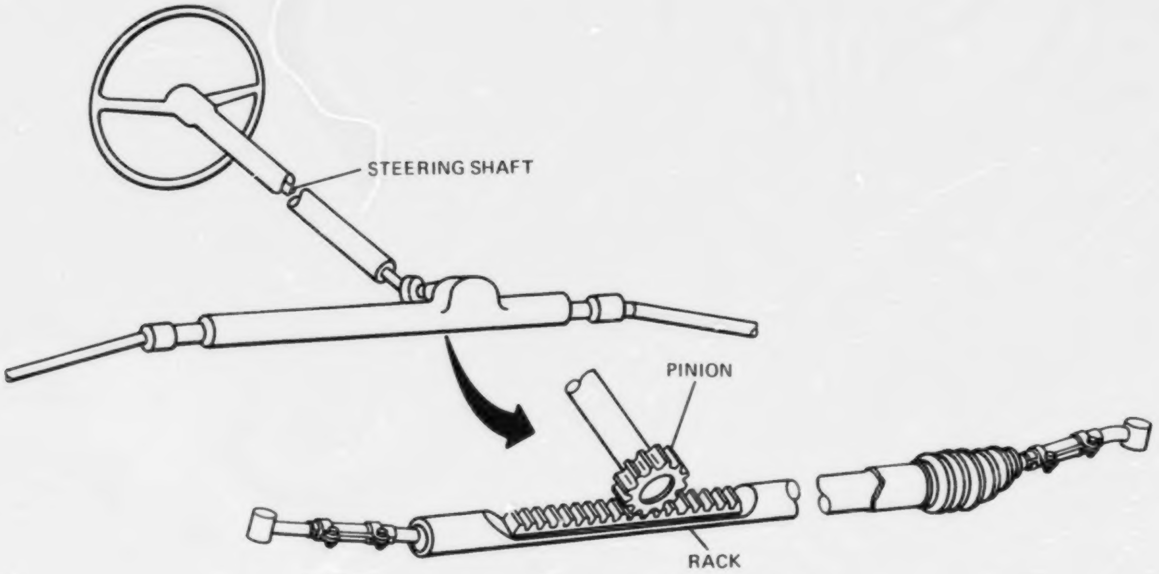


Figure 33-11. Rack and Pinion Steering Gear.

Section III. POWER STEERING – HYDRAULIC TYPE

33-9. Purpose. The power steering system is designed to reduce the effort required to turn the steering wheel. This task is accomplished by an auxiliary power network incorporated in the steering system.

33-10. Components.

a. Pump. All power steering systems contain a pump (fig. 33-12) that supplies hydraulic fluid under pressure to the other components in the system. The pump, which may be of the gear teeth, rotor, or vane type, usually is driven by the engine by means of a V-belt and is functional whenever the engine is operating. Some models mount the pump in front of the engine and are driven directly by the crankshaft. The pressure and flow relief valves are always built into the pump. These valves are designed to limit the amount of pressure and flow the pump develops throughout the different engine speeds.

b. Reservoir. The pump receives its oil supply from the reservoir (fig. 33-12), which usually is an integral part of the pump. Power steering fluid is generally added to the system and checked at the reservoir.

c. Control Valve. The control valve (fig. 33-13), which is actuated by the steering wheel movements, is designed to direct the hydraulic fluid under pressure to the proper location in the steering system. The control valve may be mounted either in the steering box or on the steering linkage, depending on which system configuration is being used.

d. Gearbox. The gearbox used in an integral power steering system (fig. 33-14) is basically a manual gearbox that is adapted to include a power assist package. The integral power steering gearbox are of two types: offset and in line. The offset type utilizes a recirculating ball-type gearbox with a rack meshed to the pitman sector gear above or on the opposite side of the ball nut. The power steering force is developed in the power piston, which is offset from the worm and nut and attached to the rack. The in-line design uses the recirculating ball nut assembly as a power piston. In this design, the ball nut is sealed inside a cylindrical portion of the steering gear housing. The power steering effect is produced by alternately pressurizing either side of the power piston.

e. Hydraulic Cylinder. The hydraulic cylinder that is used on the semi-integral and integral

TA233841

601

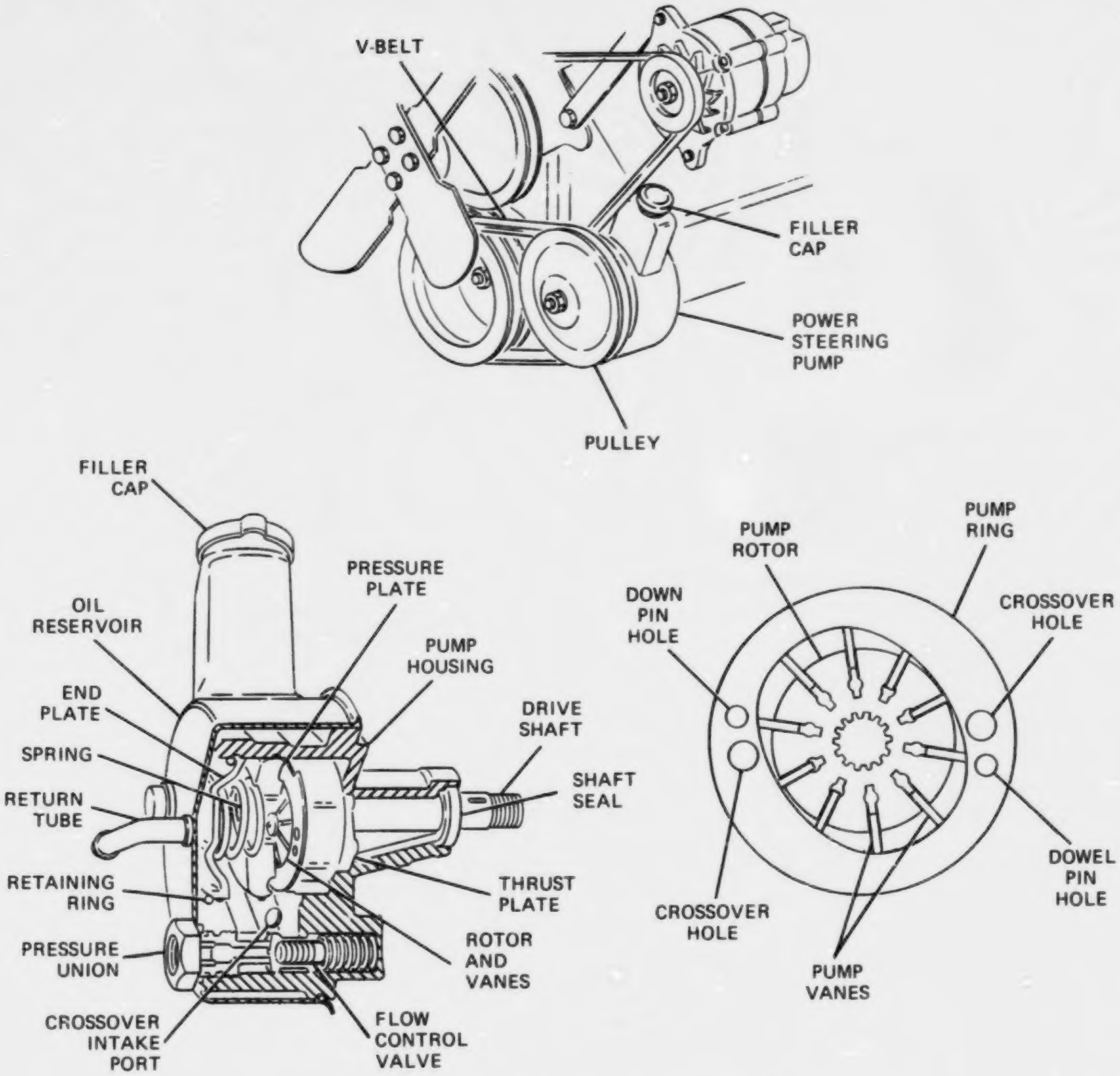

V-BELT
FILLER CAP
POWER STEERING PUMP
PULLEY
FILLER CAP
OIL RESERVOIR
END PLATE
SPRING
RETURN TUBE
RETAINING RING
PRESSURE UNION
CROSSOVER INTAKE PORT
PRESSURE PLATE
PUMP HOUSING
DRIVE SHAFT
SHAFT SEAL
THRUST PLATE
ROTOR AND VANES
FLOW CONTROL VALVE
PUMP ROTOR
PUMP RING
DOWN PIN HOLE
CROSSOVER HOLE
CROSSOVER HOLE
DOWEL PIN HOLE
PUMP VANES

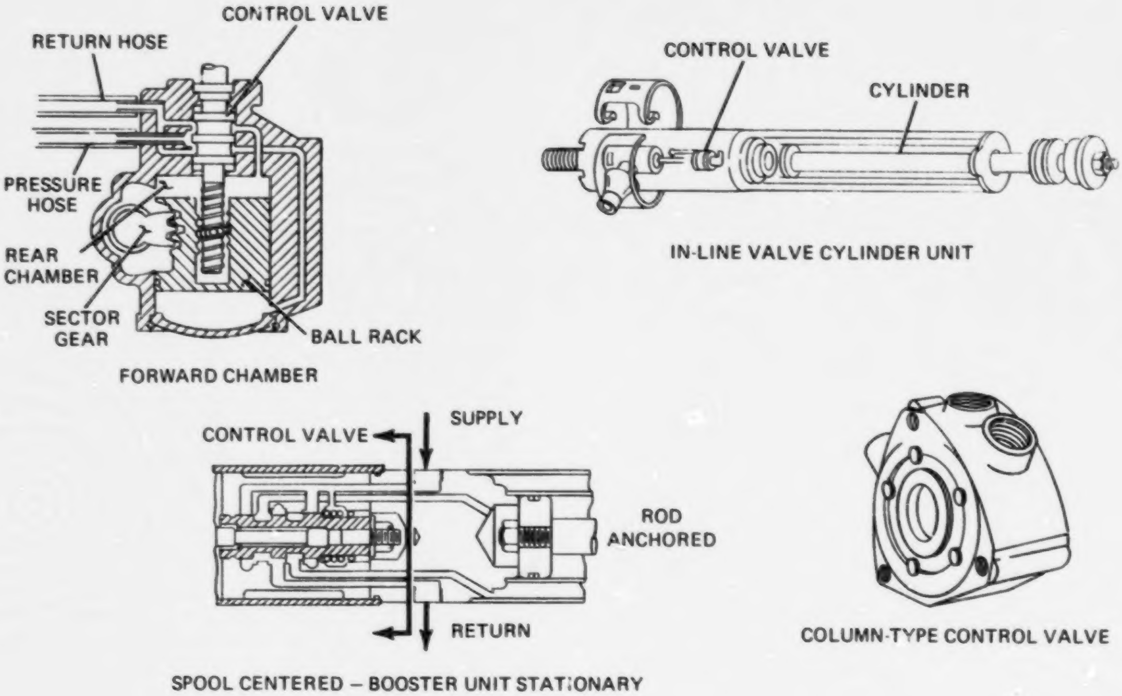
Figure 33-12. Typical Power Steering Pump.

power steering systems (fig. 33-15) is located on the steering linkage. The power assist is developed in the cylinder through the action of the pressurized hydraulic fluid. The cylinder may be single- or double-wall construction. The hydraulic hoses connect to the ports on each end of the single-wall cylinder. The double-wall cylinder has connections on one end for both hoses and an internal passageway between the walls to pressurize the other end of the cylinder. Some linkage cylinders have a shuttle valve built into the piston. This valve is designed to open at the end of the piston stroke. This feature helps eliminate full hydraulic pressure from acting on the cylinder when the piston is bottomed by opening and allowing fluid to flow through the piston.

33-11. Operation.

a. Neutral. In the neutral position (fig. 33-13) there is no force required of the power steering system to turn the wheels, therefore the fluid under pressure must be bypassed through the system. This usually is accomplished in the control valve. When there is no steering force required by the driver, the spool in the control

602


CONTROL VALVE
RETURN HOSE
PRESSURE HOSE
REAR CHAMBER
SECTOR GEAR
BALL RACK
FORWARD CHAMBER
CONTROL VALVE
CYLINDER
CONTROL VALVE
SUPPLY
ROD ANCHORED
RETURN

IN-LINE VALVE CYLINDER UNIT

SPOOL CENTERED – BOOSTER UNIT STATIONARY

COLUMN-TYPE CONTROL VALVE

Figure 33-13. Control Valve.

valve is centered by springs or hydraulic pressure or a combination of both. This allows the oil to flow through the valve and back to the reservoir. This condition allows the steering system to maintain its position.

b. Left and Right Turns. As the driver attempts to turn the steering wheel to make a left or right turn, the power steering system is activated. The spool is moved off its center position and is forced to the left or right end of the control valve (fig. 33-13). This opens the proper passageways for the pressurized oil. It is directed to the proper side of the piston in the steering box or end of the hydraulic cylinder if linkage-type power steering is employed. The return port is also opened and the fluid that is being displaced by the piston in the cylinder is allowed to return to the reservoir.

33-12. Configurations.

a. Linkage Type (A, Fig. 33-16). In the linkage configuration, the control valve and power cylinder may be separate parts and mounted on different parts of the linkage.

b. Integral (B, Fig. 33-16). The integral system incorporates the control valve and power assist into the steering gear as a unit.

c. Semi-Integral (C, Fig. 33-16). The control valve on the semi-integral system is mounted to the steering gear and a separate hydraulic cylinder is mounted to the linkage.

TA233843

603

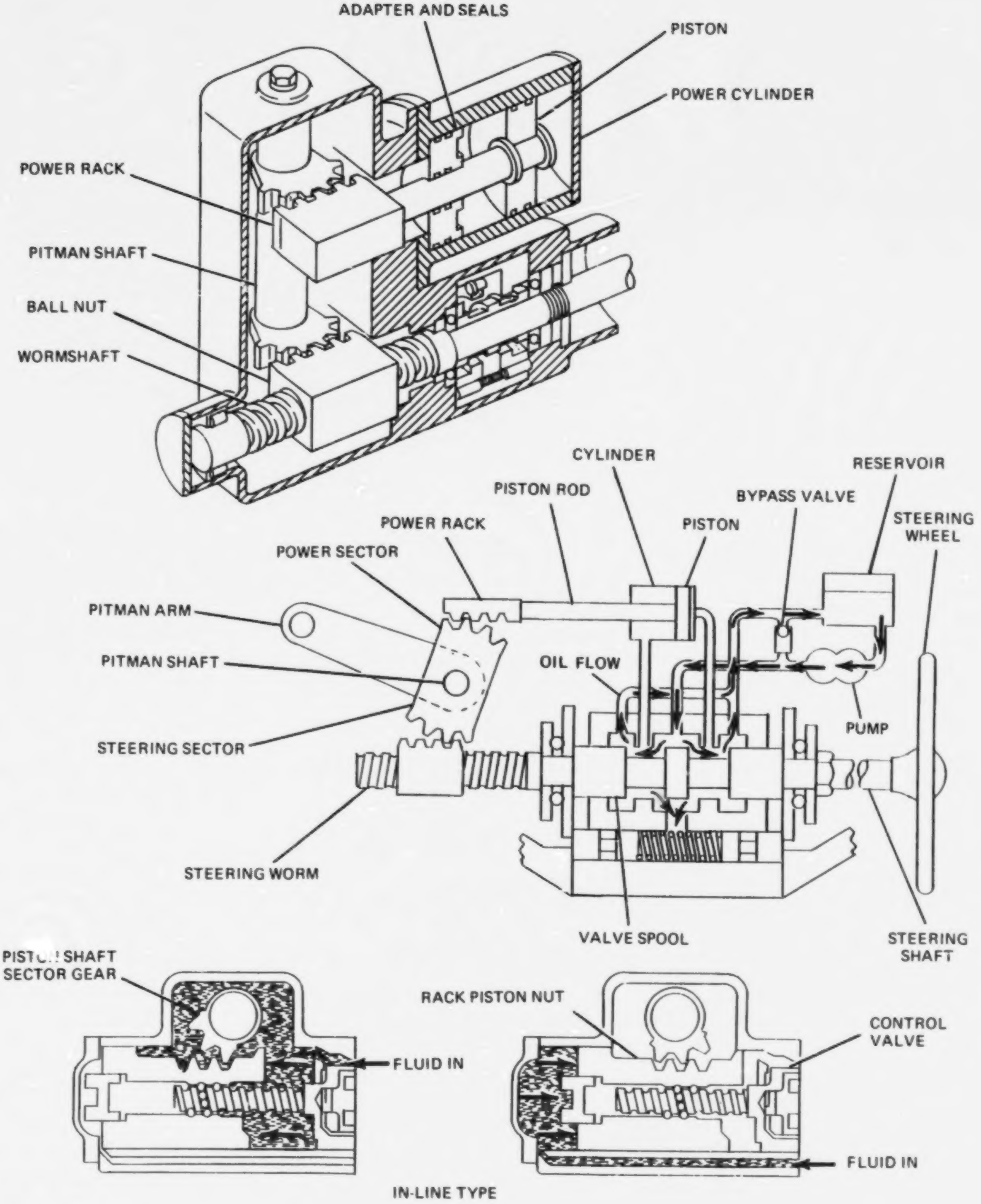

ADAPTER AND SEALS
PISTON
POWER CYLINDER
POWER RACK
PITMAN SHAFT
BALL NUT
WORMSHAFT
CYLINDER
RESERVOIR
PISTON ROD
BYPASS VALVE
STEERING WHEEL
POWER RACK
PISTON
POWER SECTOR
PITMAN ARM
PITMAN SHAFT
OIL FLOW
PUMP
STEERING SECTOR
STEERING WORM
VALVE SPOOL
STEERING SHAFT
PISTON SHAFT SECTOR GEAR
RACK PISTON NUT
CONTROL VALVE
FLUID IN
FLUID IN
IN-LINE TYPE

Figure 33-14. Power Steering Gearbox.

TA233844

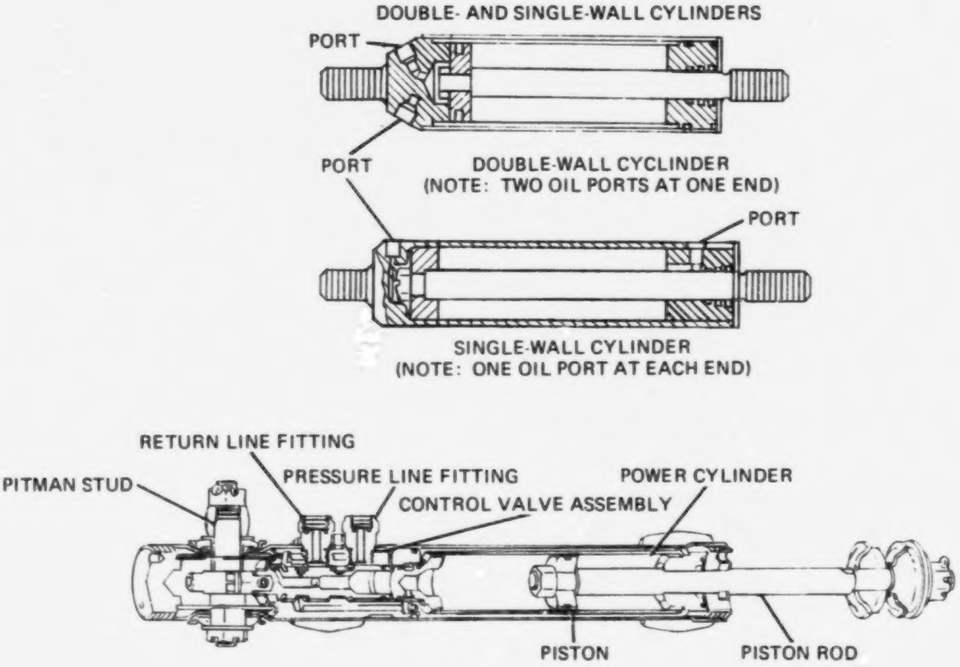

DOUBLE- AND SINGLE-WALL CYLINDERS
PORT
PORT
DOUBLE-WALL CYCLINDER
(NOTE: TWO OIL PORTS AT ONE END)
PORT
SINGLE-WALL CYLINDER
(NOTE: ONE OIL PORT AT EACH END)
RETURN LINE FITTING
PITMAN STUD
PRESSURE LINE FITTING
POWER CYLINDER
CONTROL VALVE ASSEMBLY
PISTON
PISTON ROD

Figure 33-15. Hydraulic Cylinder.

TA233845

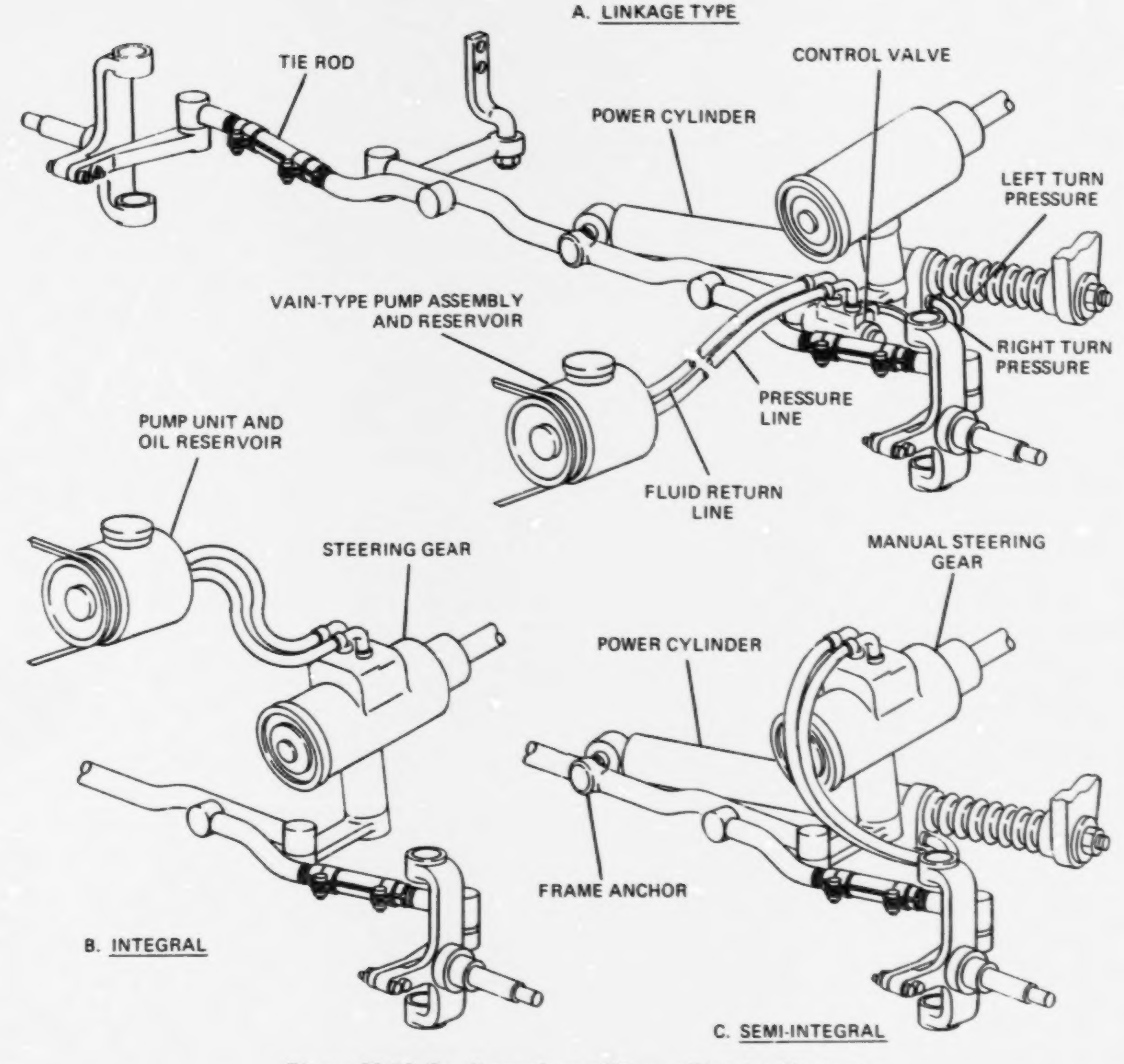

A. LINKAGE TYPE
TIE ROD
CONTROL VALVE
POWER CYLINDER
LEFT TURN PRESSURE
VAIN-TYPE PUMP ASSEMBLY AND RESERVOIR
RIGHT TURN PRESSURE
PRESSURE LINE
PUMP UNIT AND OIL RESERVOIR
FLUID RETURN LINE
STEERING GEAR
MANUAL STEERING GEAR
POWER CYLINDER
FRAME ANCHOR
B. INTEGRAL
C. SEMI-INTEGRAL

Figure 33-16. Configurations of Power Steering Systems.

Section IV. AIR STEERING

33-13. Purpose. Heavy vehicles are difficult to steer because large loads on the tires tend to increase their turning resistance. This problem cannot be overcome satisfactorily by using a steering gear with a very high reduction ratio because it would require numerous revolutions of the steering wheel to turn the vehicle wheels; therefore, some form of power steering to aid the driver in steering the heavier vehicles is required. Air steering is a desirable method of power steering, because the heavier vehicles on which it would be used usually have an airbraking system from which the air pressure can be obtained. If there is no airbraking system, an air compressor and reservoir are required to obtain the necessary air pressure.

33-14. Components. Air steering control consists primarily of three major units: a combination of levers mounted on the steering gear pitman arm shaft; two control valves; and an air cylinder containing a double-acting piston (fig. 33-17).

TA233846

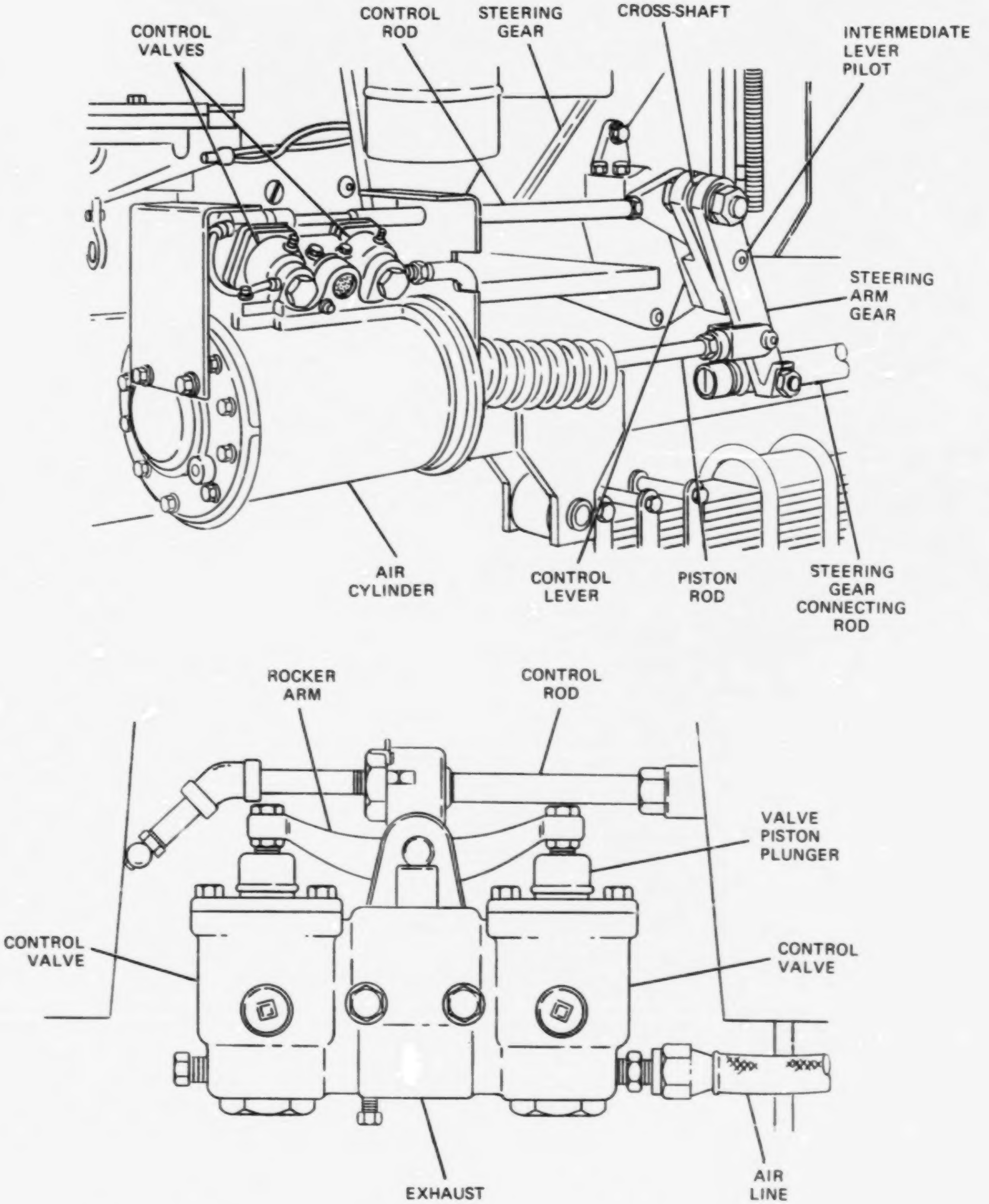

CONTROL VALVES
CONTROL ROD
STEERING GEAR
CROSS-SHAFT
INTERMEDIATE LEVER PILOT
STEERING ARM GEAR
AIR CYLINDER
CONTROL LEVER
PISTON ROD
STEERING GEAR CONNECTING ROD
ROCKER ARM
CONTROL ROD
VALVE PISTON PLUNGER
CONTROL VALVE
CONTROL VALVE
EXHAUST
AIR LINE

Figure 33-17. Air Steering.

TA233847

The control valves are mounted directly on the air cylinder, each valve controlling one side of the cylinder. The air pressure delivered from the air line to the cylinder is proportional to the force applied on the top of the valve piston plunger by the control rod. The valves are actuated by a rocker arm so that air is delivered to one side of the cylinder at a time. These valves are adjusted so that the air can be exhausted from both sides of the cylinder simultaneously, but air pressure can be delivered to only one side at a time (fig. 33-17).

33-15. Operation.

a. Neutral. In the neutral position the force on the steering wheel is removed, the steering wheel position remains constant, and the control linkage shifts and shuts off the air supply to the air cylinder. When this happens, the air cylinder remains pressurized in that position and holds the steering linkage steady until the steering wheel is turned again.

b. Right and Left Turns. If the steering wheel is turned in one direction, the steering linkage shifts one way and the control valves allow one side of the cylinder to exhaust while pressurizing the opposite side. The piston rod then extends or retracts, providing the power steering assist to the linkage.

Section V. FOUR-WHEEL DRIVING AND STEERING

33-16. Construction.

a. Four-Wheel Drive. A construction in which all four wheels of the vehicle drive, is used on many military vehicles. A typical construction for a wheel that drives and steers is illustrated in figure 33-18. A universal joint is used at the end of the axle shaft so that the wheel will be free to pivot at the end of the axle, as well as be driven through the axle. The end of the axle housing encloses this universal joint and is provided with vertical trunnion pins that act as a steering knuckle pivot. The wheels, mounted on steering knuckles attached to these trunnion pivots, are free to turn around the pivots at the same time they are driven through universal joints on the inner axle shaft. Steering knuckle arms are mounted on the steering knuckles so that the wheels can be turned around the trunnion steering pivots by the steering linkage.

b. Four-Wheel Steering. All four wheels can be steered from the steering wheel by connecting the steering linkage of these wheels to the pitman arm (fig. 33-19). The rear wheels are connected together by knuckle arms and a tie rod. Because the rear wheels must be turned in the opposite direction to the front wheels to travel in the same arcs around the center of rotation, the drag links to the front and rear wheel steering linkage cannot be connected directly to the steering gear arm. The drag link to the front wheels must move forward while the drag link to the rear wheels moves rearward, and vice versa. To accomplish this, an intermediate steering gear arm is pivoted on the frame side member near the middle of the vehicle. The drag links are connected to opposite ends of this arm so that, as it is turned by direct connection to the pinion arm (by means of an intermediate drag link), the front and rear drag links are moved in opposite directions.

608

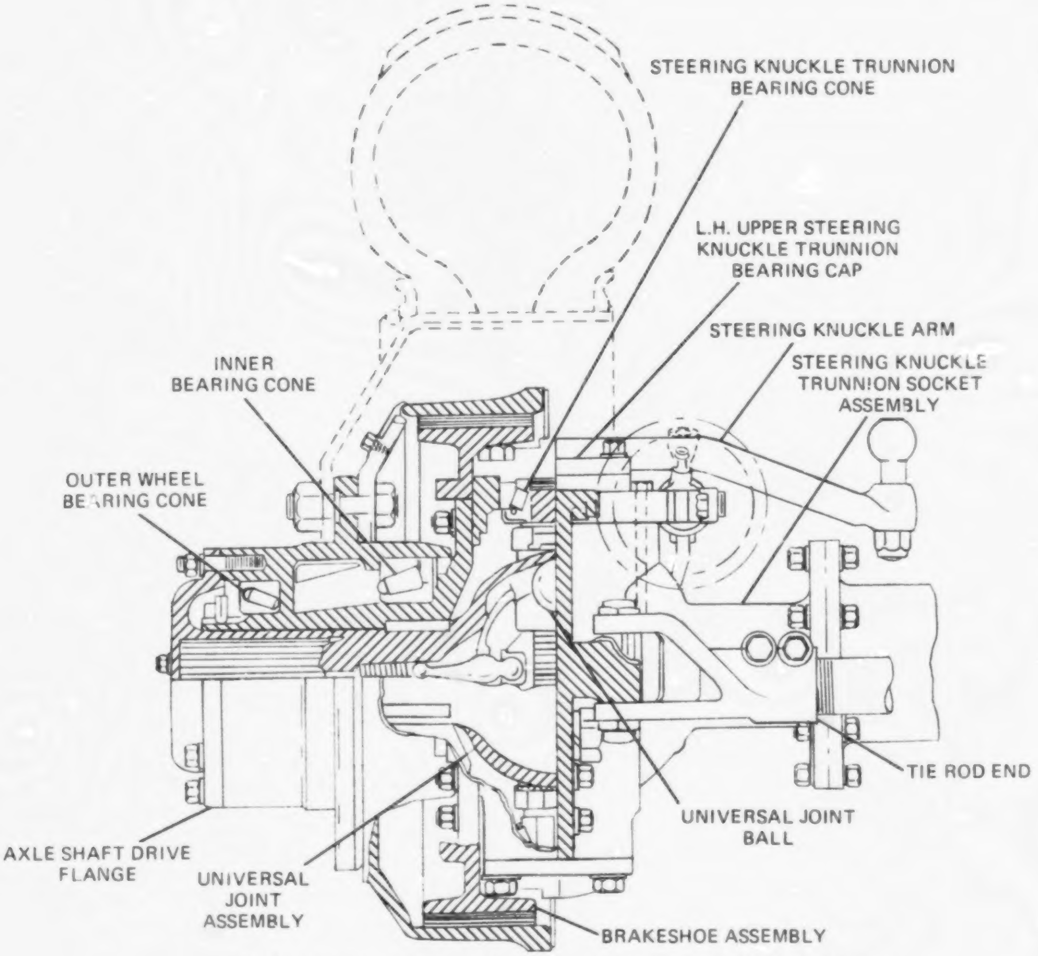
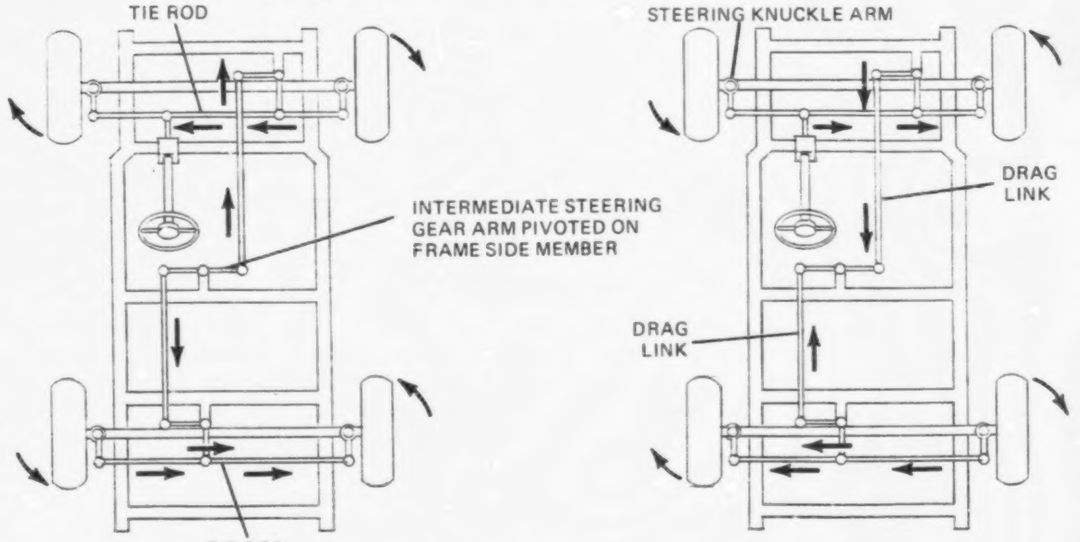

STEERING KNUCKLE TRUNNION BEARING CONE
L.H. UPPER STEERING KNUCKLE TRUNNION BEARING CAP
STEERING KNUCKLE ARM
STEERING KNUCKLE TRUNNION SOCKET ASSEMBLY
INNER BEARING CONE
OUTER WHEEL BEARING CONE
TIE ROD END
UNIVERSAL JOINT BALL
AXLE SHAFT DRIVE FLANGE
UNIVERSAL JOINT ASSEMBLY
BRAKESHOE ASSEMBLY

Figure 33-18. Axle End Construction for Four-Wheel Drive.


TIE ROD
STEERING KNUCKLE ARM
DRAG LINK
INTERMEDIATE STEERING GEAR ARM PIVOTED ON FRAME SIDE MEMBER
DRAG LINK
TIE ROD

TA233848

Figure 33-19. Four-Wheel Steering.

609

Section VI. WHEEL ALINEMENT PRINCIPLES

33-17. Steering Geometry/Toe-Out. The front end assembly of the modern motor vehicle requires careful design and adjustment because each front wheel is pivoted separately on a steering knuckle. Because of this construction, the front wheels are not in the same radius line (drawn from the center of rotation (fig. 33-20)) when a vehicle is making a turn. Because each wheel should be at right angles to its radius line, it is necessary for the front wheels to assume a toed-out position when rounding curves. If they do not, the tires slip, which causes excessive tire wear. The inner wheel (the one closer to the center of rotation) turns more than the outer wheel, so it will travel in a smaller radius. This difference in the turning ratios of the two wheels is called toe-out. It is usually specified as the number of degrees over 20 that the inner wheel is turned when the outer wheel is turned 20 degrees. Toe-out on turns may be checked but there is no provision made for its adjustment. The steering linkage must be examined carefully for bent or defective parts if this angle is not within the manufacturer's specifications.

33-18. Caster. Caster is the angle (fig. 33-21), measured in degrees, that the steering knuckle pivots are tilted forward or backward from the vertical axis when viewed from the side. Caster tends to keep the front wheels pointed straight ahead, making it easier to return the wheels to a straight ahead position after a turn has been made. The principle is the same as that used in tilting the front fork of a bicycle, which makes it possible to ride the bicycle without firmly holding the handlebars. Part of the effort applied for turning castered wheels out of the straight ahead position slightly raises the front end of the vehicle upward. Consequently, when the steering gear is released, the weight of the vehicle forces the front end down and straightens the wheels. Caster is designated as positive for backward tilt and negative for forward tilt of the steering knuckle pivots viewed from the side. Caster may be obtained on a solid axle suspension by inserting a thin wedge or shim between the axle and the spring. The axle can be made so that the supports for the steering knuckle pivots are tilted vertically. In parallel arm suspension, caster is obtained by mounting the steering knuckle support in the control arms so that it is tilted to the desired amount. If the axis of the steering knuckle pivot is

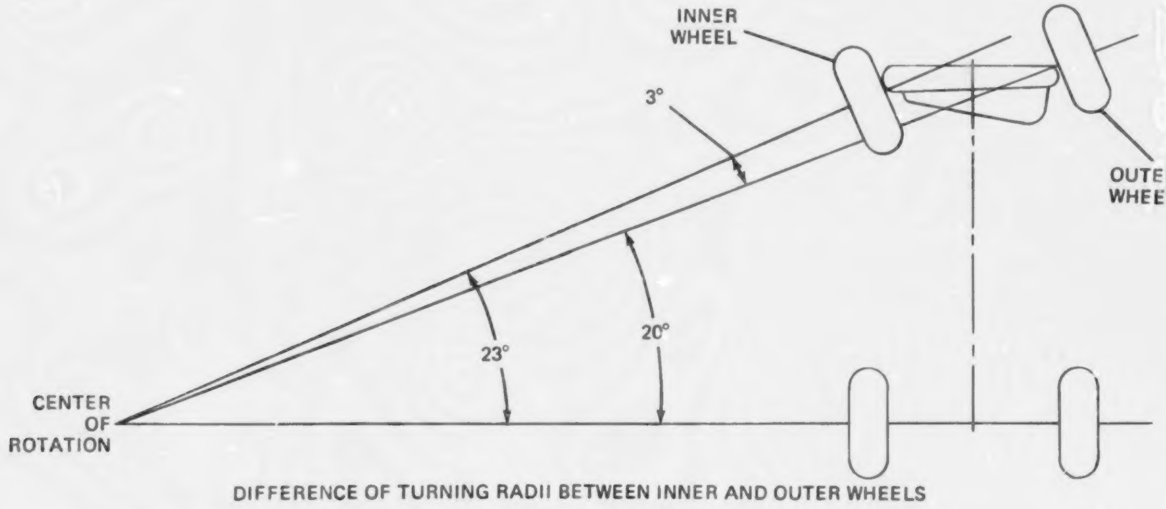


Figure 33-20. Steering Geometry, Illustrating Toe-Out.

TA233849

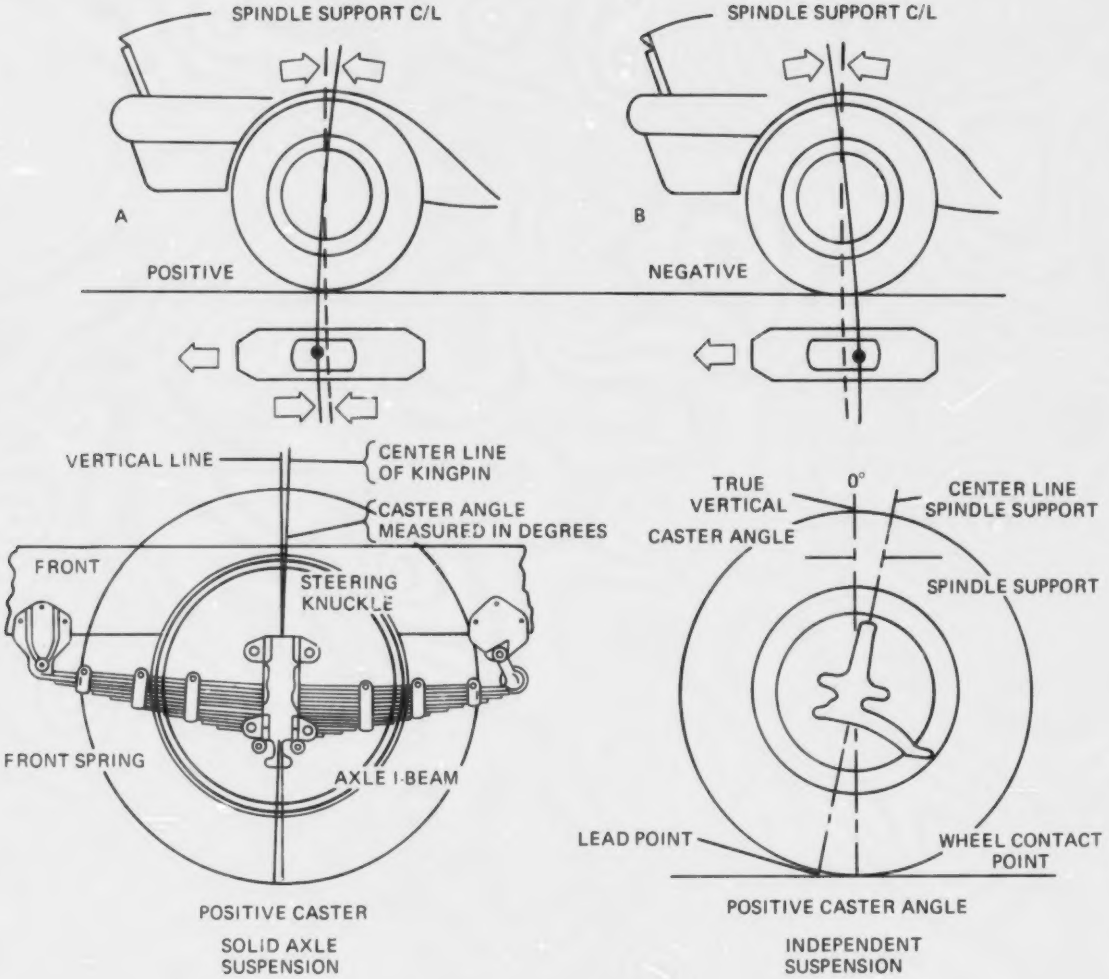

SPINDLE SUPPORT C/L
A
POSITIVE
SPINDLE SUPPORT C/L
B
NEGATIVE
VERTICAL LINE
CENTER LINE OF KINGPIN
CASTER ANGLE MEASURED IN DEGREES
FRONT
STEERING KNUCKLE
FRONT SPRING
AXLE I-BEAM
POSITIVE CASTER
SOLID AXLE SUSPENSION
TRUE VERTICAL
0°
CENTER LINE SPINDLE SUPPORT
CASTER ANGLE
SPINDLE SUPPORT
LEAD POINT
WHEEL CONTACT POINT
POSITIVE CASTER ANGLE
INDEPENDENT SUSPENSION

Figure 33-21. Caster Angle.

extended, it must strike the ground ahead or behind the point where the tire meets the ground. The caster varies from about 1/2 to 3 degrees.

33-19. Camber. Wheel camber (fig. 33-22) is the angle made by the wheel with the vertical axis when it is in the straight ahead position. Positive cambered wheels are closer together at the bottom than they are at the top. For many years, front-wheel camber as great as 3 degrees has been used. For driving on crowned roads, this camber permitted better rolling contact by bringing the wheel perpendicular to the road and made steering easier. In recent years, the construction of graded roads and the use of low-pressure tires has led to a decrease in camber. If the vehicle were run on a flat road and had no lost motion at the bearings, zero camber would be ideal; but it is not practical to build front axles with zero camber because of the possible accumulation of bearing clearances and the slight deflection of the axle under the vehicle load. Therefore, a camber of about 1 degree is recommended at present. Excessive camber causes continual slippage of the tire on the road, because each wheel tries to follow a path away from that traveled by the vehicle. This is due to the fact that a cambered wheel tends to roll like a cone because its axis is not horizontal.

33-20. Kingpin Inclination. Kingpin, or pivot, inclination (fig. 33-23) is the amount in degrees that the steering knuckle pivots are tilted sideways toward the center of the vehicle. Inclination of the

TA233850

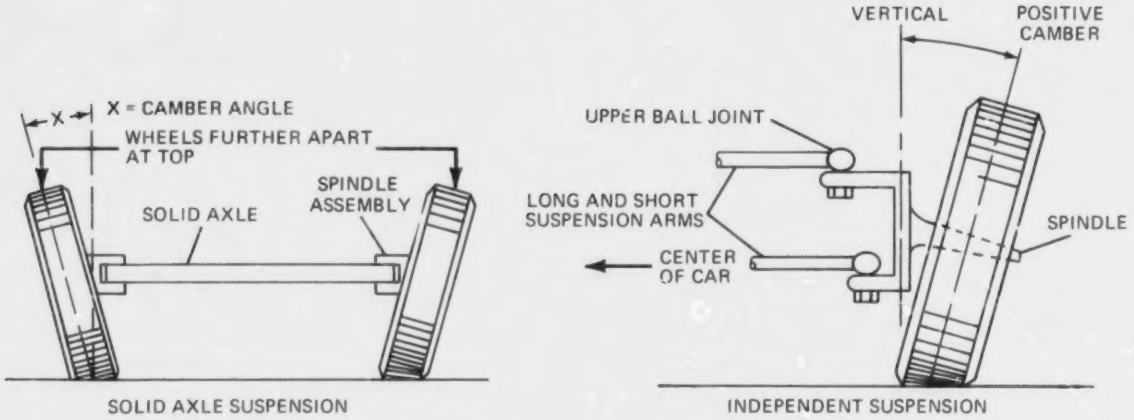

X = CAMBER ANGLE
X
WHEELS FURTHER APART AT TOP
SPINDLE ASSEMBLY
SOLID AXLE
SOLID AXLE SUSPENSION
VERTICAL
POSITIVE CAMBER
UPPER BALL JOINT
LONG AND SHORT SUSPENSION ARMS
CENTER OF CAR
SPINDLE
INDEPENDENT SUSPENSION

Figure 33-22. Camber Angle.

steering knuckle pivots tends to keep the wheel spindles pointed outward in line with the axle, just as caster tends to keep the wheels of a vehicle pointed straight ahead. The effect is the same and also will result in easier steering. Setting the steering knuckle pivot at an angle causes the pivot axis to meet the ground close to the center of the tire contact (fig. 33-23). The wheel, therefore, has a small turning radius so that it will be easy to turn and will roll in a very small arc on the ground. Too much inclination makes it difficult to park a vehicle because, if the intersection of the pivot axis to the ground falls at the center of the tire contact with the ground, the tire slides rather than rolls when the wheel is turned on a stationary vehicle. Pivot inclination is usually from 3 to 7 degrees. Careful distinction should be made between camber and kingpin inclination. They are closely related and dependent on each other. Wheels with large camber require large kingpin inclination and those with small camber require small kingpin inclination. Pivot inclination allows the front wheel brakes to be applied with little affect on steering.

33-21. Toe-In. Toe-in (fig. 33-24) is the amount in inches that the wheels point in; that is, the distance between the front wheels is less at the front than it is at the rear. Toe-in and camber are definitely related and depend on the crown of the road. For a flat road, experience indicates that a desirable condition is to have zero camber and zero toe-in. However, such a condition is difficult to maintain. Toe-in balances the effect of camber

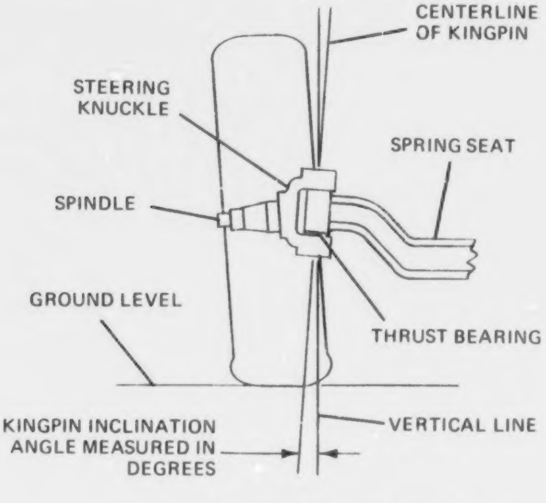
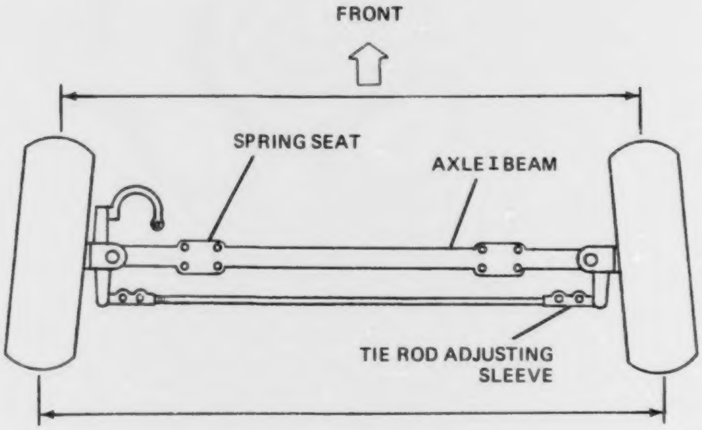

CENTERLINE OF KINGPIN
STEERING KNUCKLE
SPRING SEAT
SPINDLE
GROUND LEVEL
THRUST BEARING
KINGPIN INCLINATION ANGLE MEASURED IN DEGREES
VERTICAL LINE

Figure 33-23. Kingpin Inclination.

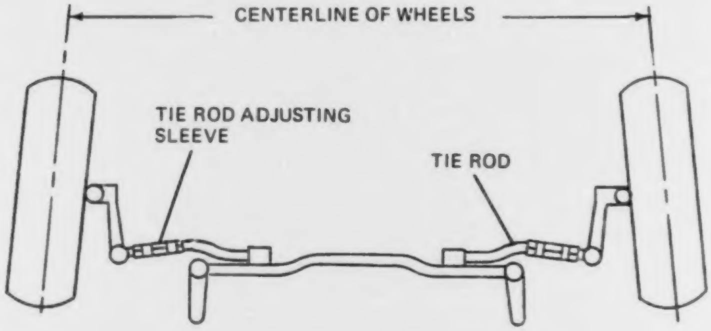
TA233851

612

BEST COPY AVAILABLE



SOLID AXLE SUSPENSION



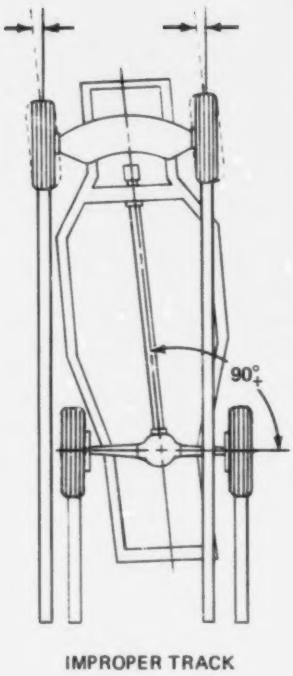
INDEPENDENT SUSPENSION

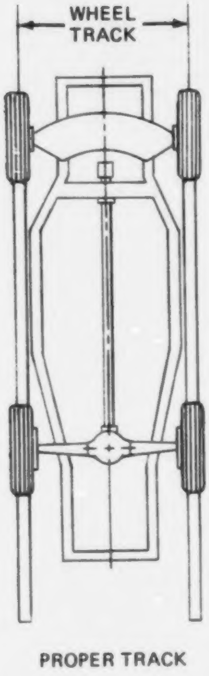
Figure 33-24. Toe-In.

on the tires. The natural tendency of the wheel is to rotate like a cone around this point. If both front wheels are forced to follow a straight path by the motion of the vehicle, there is a continual tendency for tires to slip away from each other. Toed-in wheels tend to travel toward each other and counteract this condition. By properly relating camber and toe-in, tire wear is reduced to a minimum, the motion of the wheel is balanced between two opposing forces, and pull on the steering mechanism is reduced. The amount of toe-in is adjustable by changing the length of the tie rod(s).

33-22. Tracking. Tracking (fig. 33-25) is the ability of the vehicle to maintain a right angle between the centerline of the vehicle and both the front and rear axles or spindles. If this angle is off, the vehicle will appear to be going sideways down a straight road. This problem could be caused by shifted or broken leaf springs or a bent or broken rear axle or control arms.

613


90°
IMPROPER TRACK


WHEEL TRACK
PROPER TRACK

REAR WHEELS MUST TRACK CORRECTLY

Figure 33-25. Tracking.

TA233853

614

CHAPTER 34

BRAKING SYSTEMS

Section I. PRINCIPLES OF BRAKING

34-1. Braking Action. Braking action is the use of a controlled force to accomplish the three basic tasks of reducing speed, stopping, and holding an object in a stationary position. Braking action usually is accomplished by rubbing two surfaces together that cause friction and heat (fig. 34-1). Friction is the resistance to relative motion between two surfaces in contact. The mechanical energy of friction then is transformed into heat energy. Heat energy is an unwanted product of friction and must be dissipated to the surrounding environment as efficiently as possible. Automotive vehicles use this rubbing action to develop the friction required for braking. Braking action also may be accomplished by establishing a rubbing contact with the roadway, as is done by some trolleys, which apply a braking surface to the rails.

34-2. Braking Requirements. It is known that to increase a vehicle's speed requires an increase in the power output of the engine. It also is true, although not so apparent, that an increase in speed requires an increase in the braking action required to bring a vehicle to a stop (fig. 34-2). A moving vehicle, just as any other moving body, has what is known as kinetic energy. Kinetic energy is the energy an object possesses due to its relative motion and may be expressed as 1/2 (mass) x $(\text{velocity})^2$. This kinetic energy, which increases with the square of the speed, must be overcome by braking action. If the speed of a vehicle is doubled, its kinetic energy is increased fourfold; four times as much energy, therefore, must be overcome by the braking action. Brakes must not only be capable of stopping a vehicle, but must stop it in as short a distance as possible. Because brakes are expected to decelerate a vehicle at a faster rate than the engine can accelerate it, they must be able to control a greater power than that developed by the engine. This is the reason that well-designed, powerful brakes have to be used to control the modern high-speed motor vehicle. It is possible to accelerate an average passenger car with an 80-hp engine from a standing start to 80 mph in about 36 seconds. By applying the full force of the brakes, such a vehicle can be decelerated from 80 mph to a full stop in about 4.5 seconds. The time required to decelerate to a stop is one-eighth the time required to accelerate from a standing

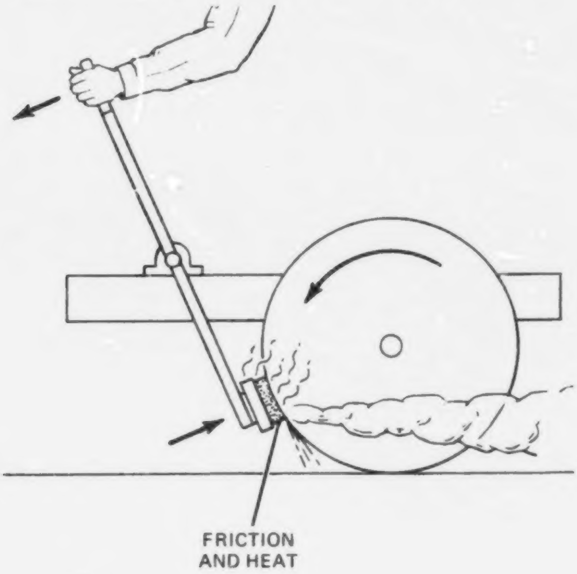


Figure 34-1. Development of Friction and Heat.

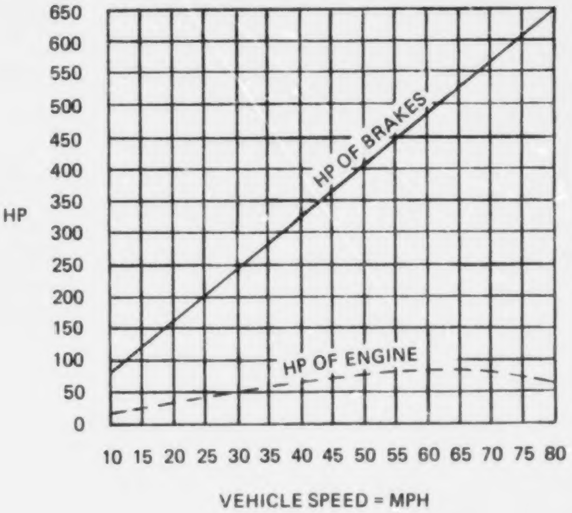


Figure 34-2. Braking Requirements.

TA233854

615

start, therefore the brakes harness eight times the power developed by the engine. Thus, about 640 (8 x 80) hp has to be spent by the friction surfaces of the brakes of an average passenger car to bring it to a stop from 80 mph in 4.5 seconds.

34-3. Vehicle Stopping Distance. Driver reaction time is the time frame between the instant the driver decides that the brakes should be applied and the moment the brake system is activated. During the time that the driver is thinking of applying the brakes and moving his or her foot to do so, the vehicle will move a certain distance, depending on its speed. After the brakes are applied, the vehicle will travel an additional distance before it is brought to a stop. Total stopping distance of a vehicle is the total of the distance covered during the driver's reaction time and the distance during which brakes are applied before the vehicle stops. Figure 34-3 illustrates the total stopping distance required at various vehicle speeds, assuming an average reaction time of 3/4 second and that good brakes are applied under most favorable road conditions.

34-4. Factors Affecting Retardation. The amount of retardation obtained by the braking system of a vehicle is affected by several factors. For wheel brakes used on motor vehicles, these factors are:

a. Pressure exerted on braking surfaces (rotating and nonrotating members).

b. Weight carried on wheel.

c. Overall radius of wheel (distance from center of wheel to outer tread of tire).

d. Radius of brakedrum or rotor (rotating member).

e. Coefficient of friction between braking surfaces.

f. Coefficient of friction between tire and road.

When the radius of the wheel or weight of the vehicle is increased, the pressure required on braking surfaces also will be increased for a fixed amount of retardation. These factors are independent of the design of the braking system and generally are a fixed value. However, limitations of these factors, particulary the weight of the vehicle to be carried by the wheels, must be considered when designing a braking system. If the radius of the brakedrum or coefficient of friction between the braking surfaces is increased, less pressure will be required to obtain the same degree of retardation. The best results are obtained when these factors are correlated within the limits permitted by the design of the braking system. The coefficient of friction between tire and road determines maximum retardation obtained by the application of brakes.

34-5. Maximum Retardation Point. When brakes are applied, the wheel either will roll or skid, depending on relative values of coefficients of friction between braking surfaces and between tire and road. Heavy jamming of the braking

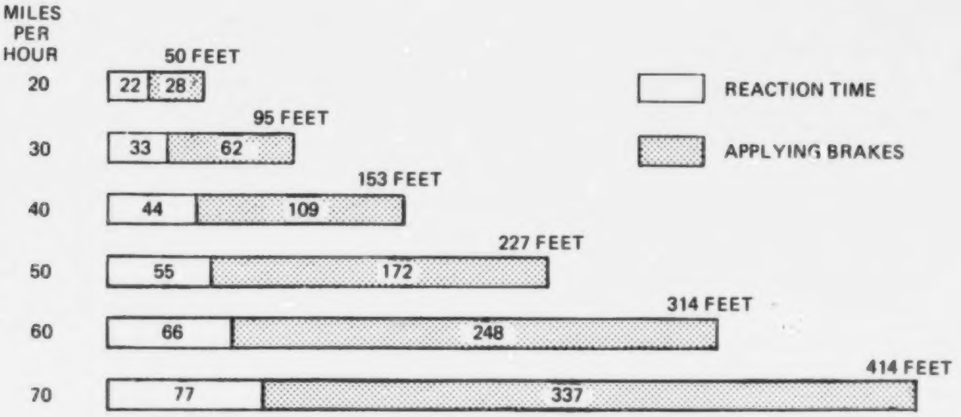


Figure 34-3. Total Vehicle Stopping Distance of an Average Vehicle.

TA233855

surfaces together will tend to increase the friction to such a degree that the wheel will lock. When this happens, braking action is caused by friction between tire and road, which heats and wears the tire. Maximum retardation is reached when friction between the brake surfaces is such that the wheel is about to lock. At this point, friction between the brake surfaces is almost the same as that between tire and road. This is the maximum amount of friction that can be used in retarding motion of the vehicle. Friction encountered between tire and road is the limiting factor of braking. Should friction between braking surfaces go beyond this, the braking surfaces will lock and the wheel will skid. The action produced when a wheel rolls and when it skids is shown in figure 34-4. When a wheel rolls along a road, there is no relative motion at the point that the tire makes contact with the road because the wheel rolls with the road surface, but when a wheel skids, there is relative motion at the point of contact because the wheel is not rotating while moving over the road surface. When a wheel skids, friction is reduced, which decreases the braking effect. Nevertheless, brakes are designed so that the vehicle operator is able to lock the wheels if he or she applies enough force on the foot pedal.

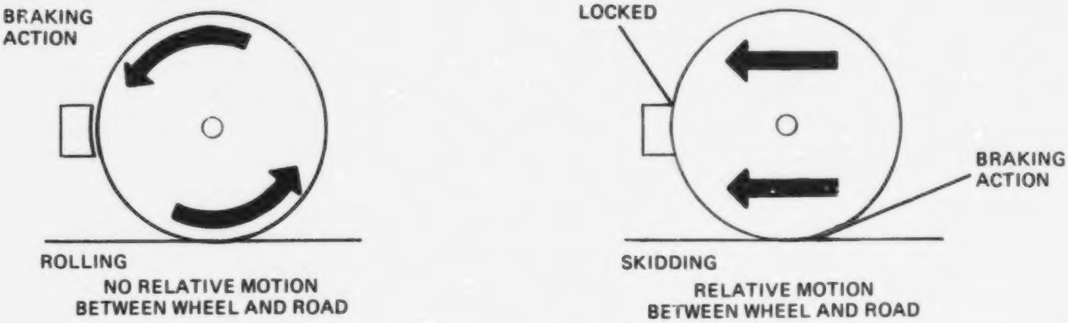

BRAKING ACTION
ROLLING
NO RELATIVE MOTION BETWEEN WHEEL AND ROAD
LOCKED
BRAKING ACTION
SKIDDING
RELATIVE MOTION BETWEEN WHEEL AND ROAD

Figure 34-4. Action During Wheel Rolling and Skidding.

TA233856

617

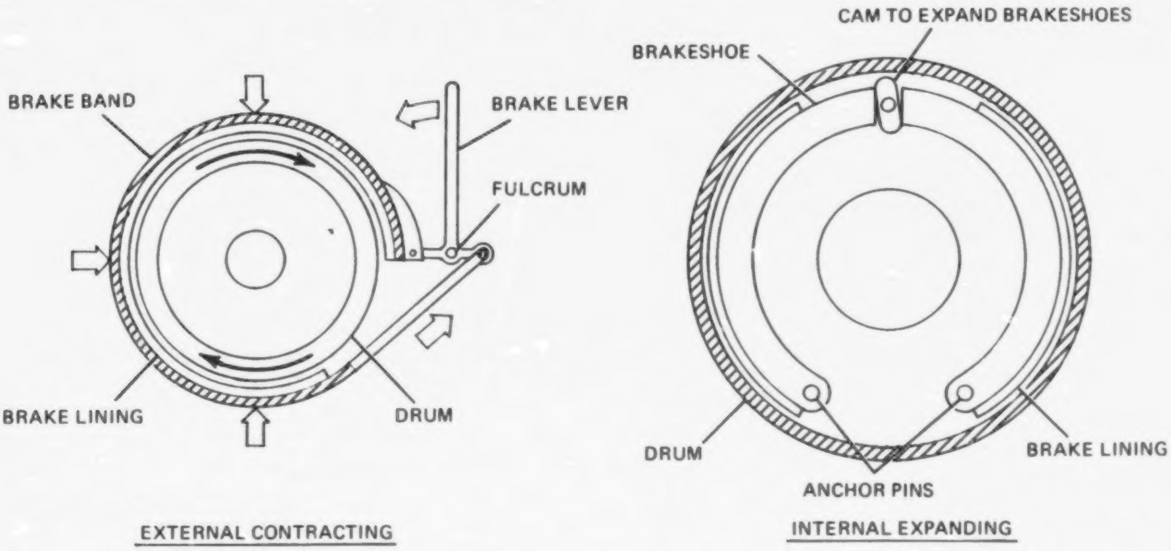
Section II. DRUM BRAKE MECHANISMS

34-6. Rotating and Nonrotating Units. There are many types of brake system designs in use on modern automotive vehicles. Regardless of the design, all systems require the use of a rotating and nonrotating unit. Each of these units houses one of the braking surfaces, which, when forced together, produce the friction required for braking action. The rotating unit on many motor vehicle wheel brakes consists of a drum that is secured to and driven by the wheel. The nonrotating unit consists of the brakeshoes and linkage required to apply the shoes to the drum. Brakes may be of the internal expanding or external contracting type (fig. 34-5), depending on how the stationary surface is forced against the rotating surface.

34-7. Construction.

a. Brakeshoes. Brakeshoes (fig. 34-6) are used to support, strengthen, and move the brake lining. Because the brake lining material is soft and brittle, it is necessary to add a supportive foundation to the lining so it will not collapse and break during use. The brakeshoes also serve to attach the brake lining to a stationary member, usually the backing plate, so the braking action may be accomplished. Brakeshoes are made of malleable iron, cast steel, drop-forged steel, pressed steel, or cast aluminum. Pressed steel commonly is used because it is cheaper to produce in large quantities. Steel shoes expand at about the same rate as the drum when heat is generated by brake application, thereby maintaining the clearance between the brakedrum and brakeshoe under most conditions. The brake lining is riveted or bonded to the face of the brakeshoe and makes contact with the inner surface of the brakedrum. Semitubular brass rivets sometimes are used to attach the brake lining to the brakeshoe. The brass rivets are chosen over other types because brass does not score the drums excessively if the lining should be neglected and worn past the point of replacement. Aluminum rivets are not used because they may corrode due to moisture. The brake lining also may be bonded directly to the brakeshoe. In this process, a special cement is used to adhere the lining to the brakeshoe. After application, the shoe is baked at a predetermined temperature to ensure proper setting of the cement. In some brake assemblies, the lining is not fastened to either the shoe or the drum, but floats between them and is held by a lining retainer on one side and the brake shield on the other.

b. Brake Lining. Variation in brake design and operating conditions make it necessary to have different types of brake linings. Brake linings come in woven and molded form (fig. 34-6). The



EXTERNAL CONTRACTING

INTERNAL EXPANDING

Figure 34-5. Internal Expanding and External Contracting Brakes.

TA233857

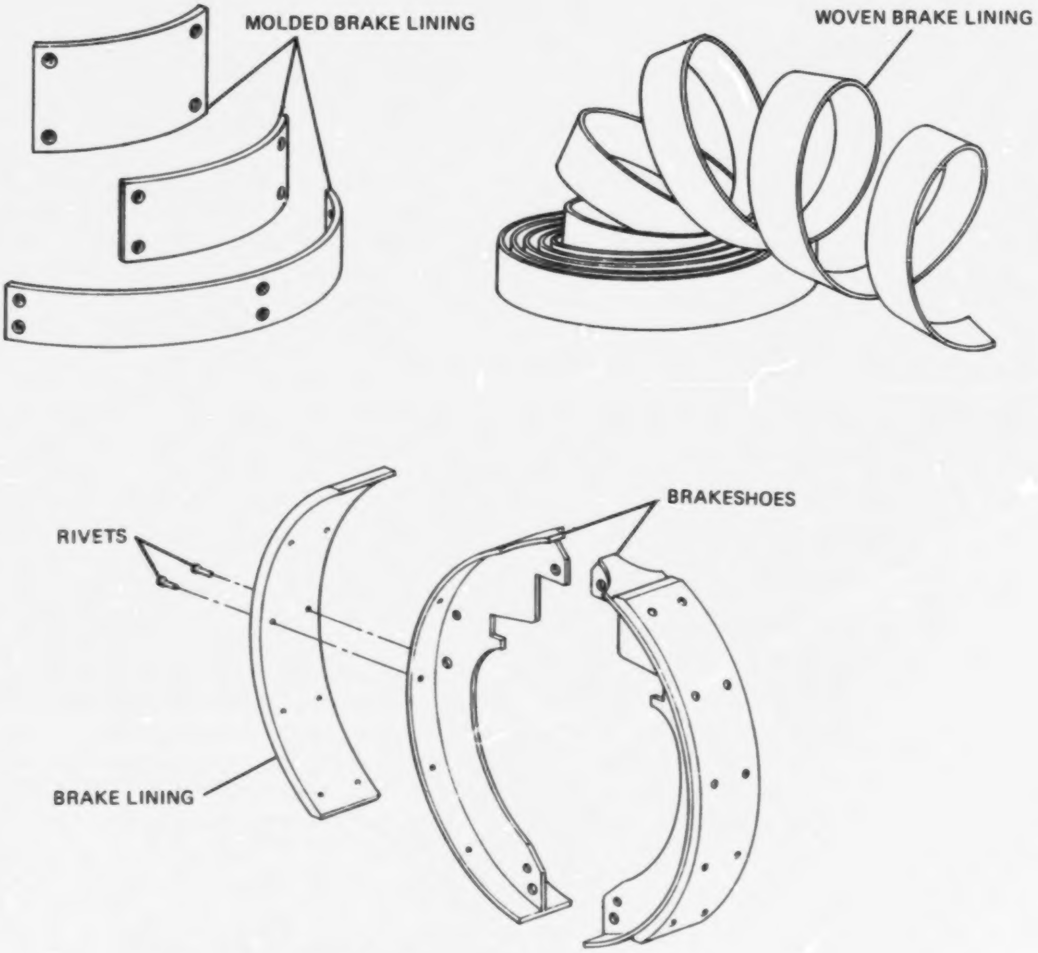


Figure 34-6. Brakeshoes and Brake Lining.

molded form currently is used on modern vehicles. Molded brake lining is made of dense compact asbestos fibers, sometimes impregnated with fine copper wire, and cut into different sizes to match the corresponding brakeshoe. These types of linings, depending on how much metal fiber is used in their construction, are referred to as nonmetallic, semimetallic, and metallic linings. The nonmetallic linings contain very few metal fibers. This type of lining is used on many modern vehicles because of its quiet operation and good heat transfer qualities. Due to the lack of metal particles, the nonmetallic linings wear well with brakedrums and do not tend to wear the drums excessively. Because the shoes are relatively soft in comparison to other types, they tend to wear faster and require replacement more often. The semimetallic linings have some metal particles in their composition. They also have good wearing properties and are quiet during application. The metallic linings have a high degree of metal fiber in their construction. They generally are characterized by small square pads bonded or welded to the brakeshoe. The pads may have a small space between them to aid in cooling. The metallic linings operate at high temperatures and may require the use of special high-temperature brake parts. The metallic brake linings generally are used for heavy-duty brake applications where large loads must be stopped or brakes are applied often.

c. Brakedrums. The brakedrum is attached to the wheel and provides the rotating surface for the brake pads to rub against to achieve the braking action. The brakedrum is grooved to

TA233858

mate with a lip on the backing plate that provides the rotating seal to help keep water and dirt from entering the brake assembly. Brakedrums may be made of pressed steel, cast iron, a combination of the two metals, or aluminum. Cast iron drums dissipate the heat generated by friction faster than steel drums and have a higher coefficient of friction with any particular brake lining. However, cast iron drums of sufficient strength are heavier than steel drums. To provide lightweight and sufficient strength, centrifuse brakedrums (fig. 34-7), made of steel with a cast iron liner for the braking surface, are used. A solid cast iron drum of the same total thickness as the centrifuse drum would be too weak, while one of sufficient strength would be too heavy for the average passenger car. Aluminum brakedrums are constructed similar to the centrifuse drums. They consist of an aluminum casting with a cast iron liner for a braking surface. This design allows heat to be transferred to the surrounding atmosphere more readily and also reduces weight. Cooling fins or ribs (fig. 34-7) also are added to most brakedrums. The fins or ribs increase the surface area of the outside portion of the brakedrum, allowing the heat to be transferred to the atmosphere more readily, thereby keeping the drum cooler and helping to minimize brake fade. For good braking action, the drum should be perfectly round and have a uniform surface. Brakedrums become out-of-round from pressure exerted by brakeshoes and from heat developed by application of the brakes. The brakedrum surface becomes scored when it is worn by braking action. When the surface is scored or the drum is out-of-round, it may be necessary to machine the brakedrum until it is smooth and true again. Care must be taken not to exceed the maximum allowable diameter according to manufacturer's specifications. If this caution is ignored, the drum can be distorted easily due to overheating, and result in brake failure. Each drum is stamped with the maximum diameter information and, if exceeded, it should be discarded and replaced with a new one.

34-8. Hydraulic Actuation. The hydraulically operated service brake uses fluid pressure to operate a hydraulic cylinder, which in turn operates the brakeshoes. The fluid pressure is generated by a hydraulic system whose operation is discussed in paragraph 34-23.

34-9. Pneumatic Actuation. The pneumatically actuated service brake uses a controlled, compressed air supply from the air system as de-

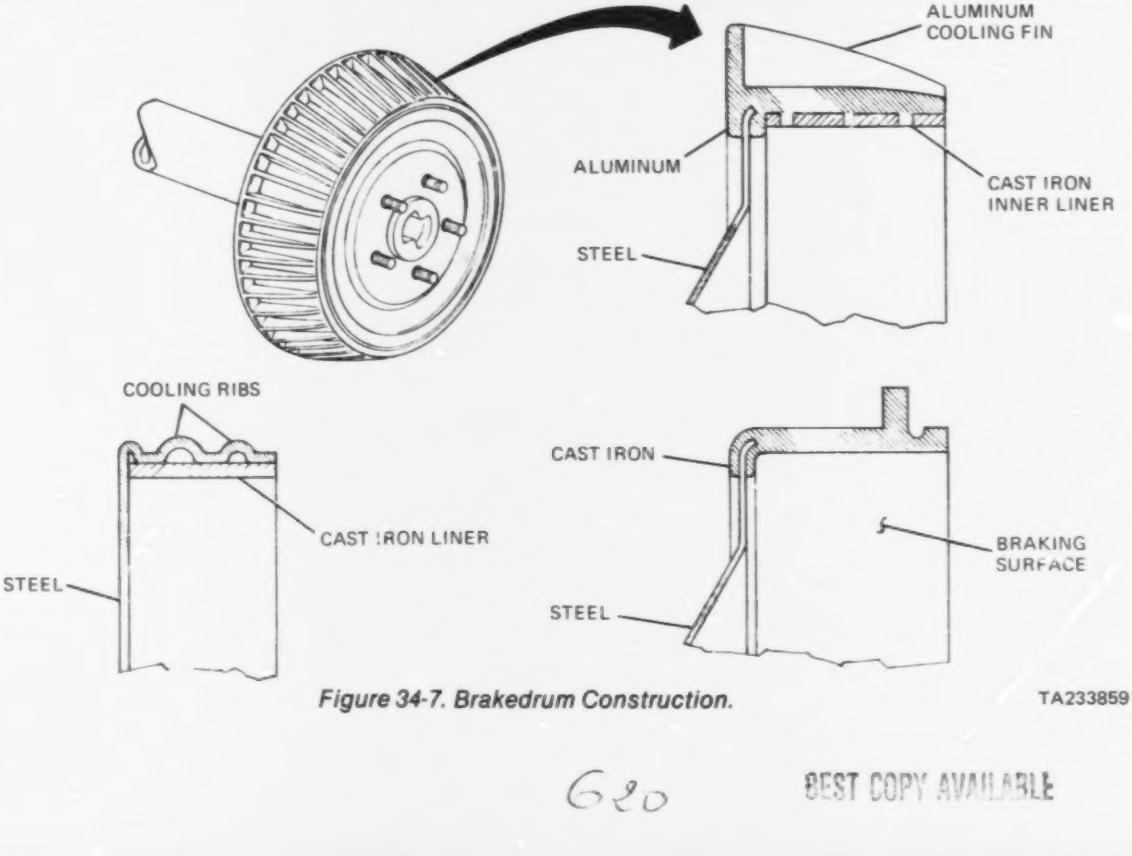


Figure 34-7. Brakedrum Construction.

TA233859

scribed in section VI. The brakes are actuated by a rotating cam, which is connected to a camshaft and in turn operates by the air system.

34-10. Operation. Brake systems, as discussed in paragraph 34-6, require a rotating and nonrotating member. In the drum brake assembly, whether hydraulically or pneumatically actuated, the drum provides the rotating member and the brakeshoe the stationary member. The primary function in the drum brake assembly is to force the brakeshoes against the rotating drum to provide the braking action. Most drum brake assemblies use what is called self-energizing action. This self-energizing action is produced as the brakeshoe engages the rotating brake-drum. As the brake actuating mechanism forces the shoes outward (A, fig. 34-8), the top of the brakeshoe tends to stick or wedge to the rotating brakedrum and rotate with it. This effect on brakeshoes greatly reduces the amount of effort required to achieve a given amount of retardation. If two brakeshoes were linked together, as shown in B, figure 34-8, application of the brakes would produce a self-energizing effect and also a servo effect. The servo effect is a result of the primary shoe, or shoe towards the front of the vehicle, attempting to rotate with the brakedrum. Due to the fact that both shoes are linked together, the rotating force of the primary shoe applies the secondary shoe. This effect is termed servo action (B, fig. 34-8). In the forward position, the anchor point for both brakeshoes is at the heel of the secondary shoe. As the vehicle changes direction, the toe of the primary shoe becomes the anchor point, and the direction of self-energizing and servo action changes (C, fig. 34-8). The most popular configurations of the drum brake assembly are discussed below.

a. Single Anchor, Self-Energizing Servo Action. In this configuration (A, fig. 34-9) both brakeshoes are self-energizing in both forward and reverse directions. The shoes are self-centering and provide servo action during brake application. This system is provided with one anchor pin, which is rigidly mounted to the backing plate and is nonadjustable. Both the forward and reverse brake torque is transmitted to the backing plate through the anchor pin. One brake cylinder with dual pistons is used in this configuration. This system is used on many modern vehicles.

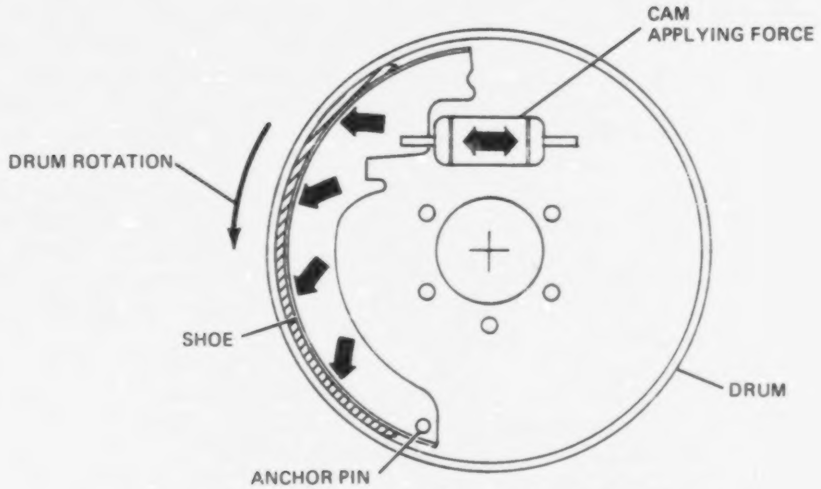
b. Single Anchor, Self-Centering. In this configuration (B, fig. 34-9), only the primary brakeshoe is self-energizing in the forward direction and therefore provides the majority of the brake force. This system is self-centering, in that the lower shoe anchor does not fix the position of the brakeshoes in relation to the drum. The shoes are allowed to move up and down as needed. Some configurations provide eccentric cams for front to rear brakeshoe adjustments. One brake cylinder is provided in this system.

c. Double Anchor, Single Cylinder. In this arrangement (C, fig. 34-9), each brakeshoe is anchored at the bottom by rotating eccentric-shaped anchor pins. Only the primary shoe is self-energizing, and the system does not develop servo action. Spring clips are used at the middle of the shoe to hold the shoes against the backing plate. Brakeshoes are adjusted manually by rotating the anchor pins. One wheel brake cylinder is provided in this arrangement.

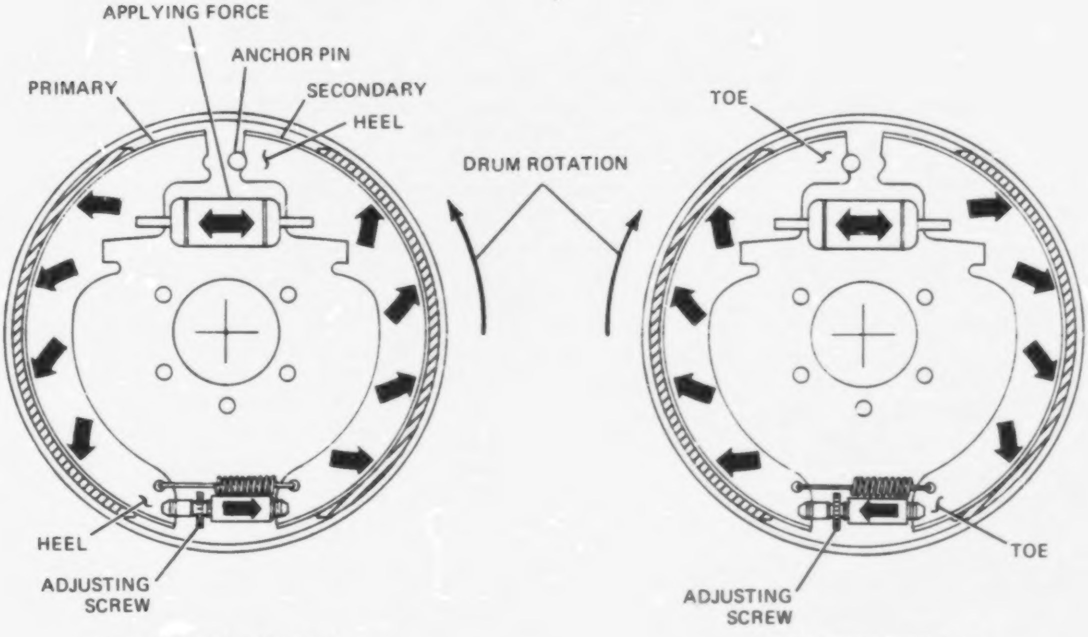
d. Double Anchor, Double Cylinder. In this system (D, fig. 34-9) the brakeshoes are provided with an anchor at each heel. The anchors are eccentric-shaped to allow for adjustment and centering. Each shoe has a single piston cylinder mounted at the toe of the brakeshoe, which allows both shoes to be self-energizing in the forward direction only. Eccentrics mounted in the middle of the shoe also allow for brake adjustment.

34-11. Disadvantages. The drum brake assembly, although well suited for the wheeled vehicle, has some disadvantages. One problem that might occur during heavy braking is what is known as brake fade. During panic stops or repeated harsh stops, brake lining and brakedrums develop large amounts of heat that reduce the coefficient of friction between brakeshoe and drum. This reduction in friction greatly decreases the vehicle's stopping ability, and in most cases, additional pressure directed on the brake pedal will not increase the vehicle's stopping performance. The enclosed design of the drum brake assembly does not allow for cooling air to enter the brake assembly and therefore heat developed during braking must be dissipated through the brakedrum and backing plate. As brakes heat up because of repeated application, cooling air flowing past the drum and backing plates is limited. This condition causes the radius of the

621


CAM
APPLYING FORCE
DRUM ROTATION
SHOE
DRUM
ANCHOR PIN

A. BRAKESHOE SELF-ENERGIZING ACTION


APPLYING FORCE
ANCHOR PIN
PRIMARY
SECONDARY
HEEL
DRUM ROTATION
TOE
HEEL
ADJUSTING SCREW
ADJUSTING SCREW
TOE

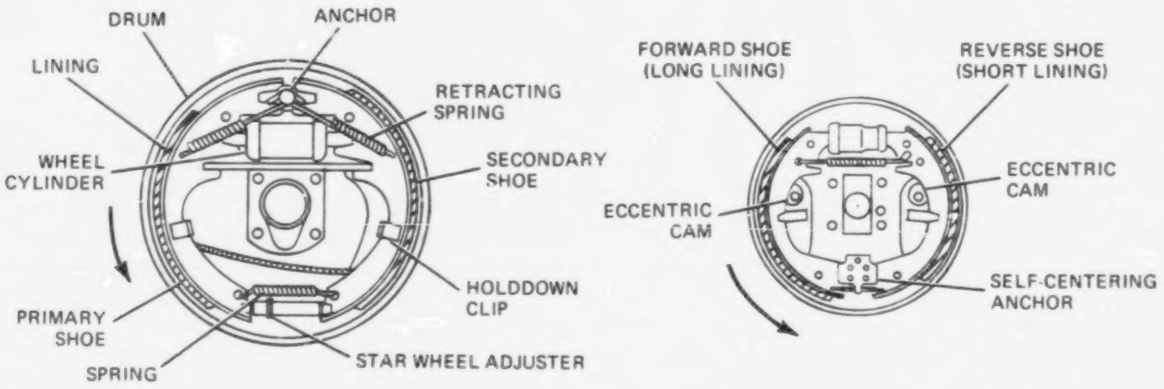
B. CAR MOVING FORWARD

C. CAR MOVING REVERSE

Figure 34-8. Self-Energizing and Servo Action.

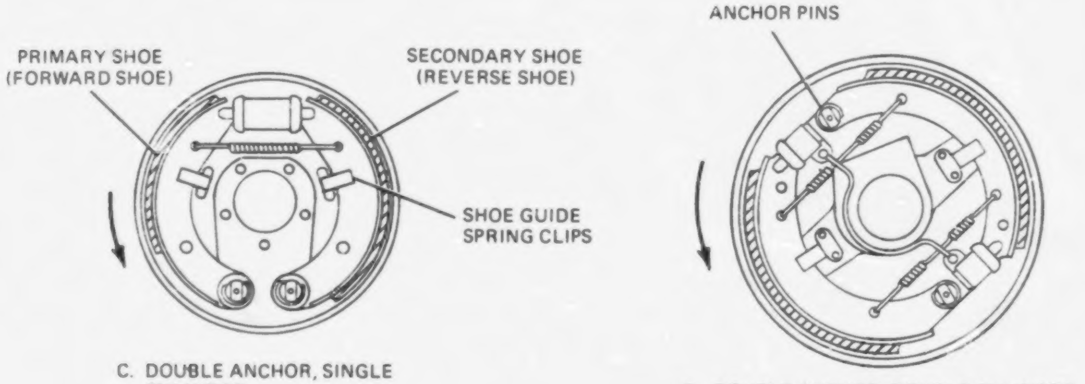
drum to increase more than the radius of the brakeshoe. As a result, a change in pressure distribution between the linings and drum occurs, which may reduce the braking ability of the vehicle up to 20 percent. The enclosed design of the drum brake assembly does not allow for water to be expelled rapidly should the brake cavity become wet due to adverse driving conditions. The water reduces the frictional properties of the brake system and must be removed to restore braking ability. This is a very dangerous situation and drastically reduces the vehicle's stopping ability until the water is discharged from the brakedrum area. The use of many springs and clips makes

TA233860


DRUM
ANCHOR
LINING
RETRACTING SPRING
WHEEL CYLINDER
SECONDARY SHOE
HOLDDOWN CLIP
PRIMARY SHOE
SPRING
STAR WHEEL ADJUSTER
FORWARD SHOE (LONG LINING)
REVERSE SHOE (SHORT LINING)
ECCENTRIC CAM
ECCENTRIC CAM
SELF-CENTERING ANCHOR

A. SINGLE ANCHOR, SELF-ENERGIZING SERVO ACTION

B. SINGLE ANCHOR, SELF-CENTERING


ANCHOR PINS
PRIMARY SHOE (FORWARD SHOE)
SECONDARY SHOE (REVERSE SHOE)
SHOE GUIDE SPRING CLIPS

C. DOUBLE ANCHOR, SINGLE CYLINDER

D. DOUBLE ANCHOR, DOUBLE CYLINDER

Figure 34-9. Drum Brake Configurations.

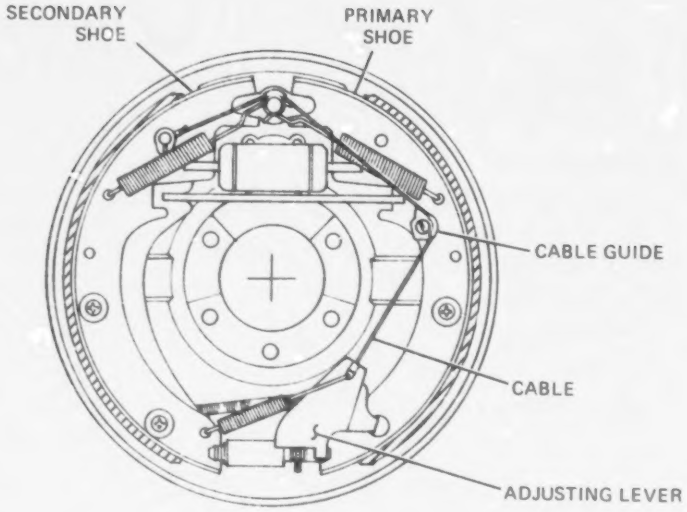
overhauling the drum brake assembly very time consuming. Because of the enclosed drum, asbestos dust is collected in the brake cavity and certain parts of the brakedrum. Asbestos is a substance that can cause cancer. Grinding linings and cleaning of the brake assembly may cause small particles of asbestos dust to become airborne. This dust is inhaled easily by the mechanic and surrounding personnel. Therefore, an approved filter mask must be worn during brake overhaul.

34-12. Self-Adjusting Mechanisms. Some drum brake assemblies are equipped with a self-adjusting system that automatically compensates for drum-to-lining clearance because drum brakes lack the inherent ability to self-adjust. After the brake system is overhauled, the initial shoe-to-drum clearance is adjusted manually. Some self-adjusting systems operate in the forward direction, some in the reverse, and others operate in both directions. The adjustment systems may be grouped into three categories: cable, link, and lever; each is discussed below.

a. *Cable Type.* The cable-type self-adjusting system (A, fig. 34-10) uses a braided steel cable and the expanding action of both brakeshoes to accomplish the self-adjusting action in the forward and reverse directions. A one-piece cable is attached to the adjusting lever and passes through a cable guide on the primary shoe. The cable then is passed up and over the anchor and attached to the secondary shoe. Operation is as follows:

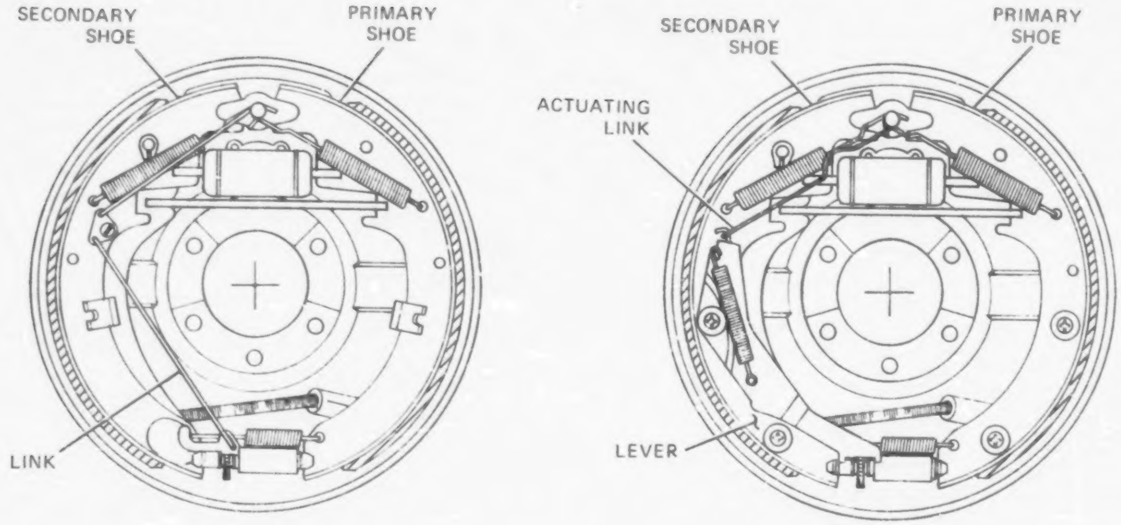
(1) Brakes are applied and the shoes expand and contact the drum.

TA233861


SECONDARY SHOE
PRIMARY SHOE
CABLE GUIDE
CABLE
ADJUSTING LEVER

A. FRONT →

CABLE TYPE


SECONDARY SHOE
PRIMARY SHOE
LINK
SECONDARY SHOE
PRIMARY SHOE
ACTUATING LINK
LEVER

B. FRONT →

LINK TYPE

C. FRONT →

LEVER TYPE

Figure 34-10. Self-Adjusting Mechanisms.

(2) The primary shoe self-energizes, and, through servo action, applies the secondary shoe.

(3) The heel of the secondary shoe is lodged against the anchor pin.

(4) The movement of the primary shoe tightens the cable by shifting the cable guide outward and in the direction of rotation.

(5) The cable then moves the adjusting lever upward. If enough shoe-to-drum clearance

TA233862

is available, the adjusting lever will engage the next tooth on the star wheel. The brakeshoes retract and the cable slackens as the brakes are released. The return spring then helps force the adjusting lever downward, which rotates the star wheel and therefore expands the brakeshoes. In the reverse direction, the toe of the primary shoe is forced against the anchor and the secondary shoe moves around to tighten the adjusting cable. The adjusting process then is completed.

b. Link Type. The link-type self-adjusting system (B, fig. 34-10) uses solid linkage rods to connect the adjusting lever to the stationary anchor point. The adjuster is operated by the two linkage rods connected together by a bellcrank, which pivots on the secondary brakeshoe. One rod attaches to the anchor point and the bellcrank, while the other rod connects the bellcrank and the adjusting lever. In this configuration, the self-adjuster works only in the reverse direction. As the vehicle is backing up and the brakes are applied, the adjusting process is as follows:

(1) The secondary shoe moves away from the anchor because of the self-energizing action.

(2) The pivot point of the bellcrank is moved in the direction of rotation.

(3) The lever moves up on the star wheel through the connection of the linkage.

If enough clearance is available between the brakeshoes and drum, the lever will engage another tooth on the star wheel. As the brakes are released, the shoes retract and the return spring helps force the adjusting lever down, therefore rotating the star wheel and expanding the adjusting screw to remove excess shoe-to-drum clearance.

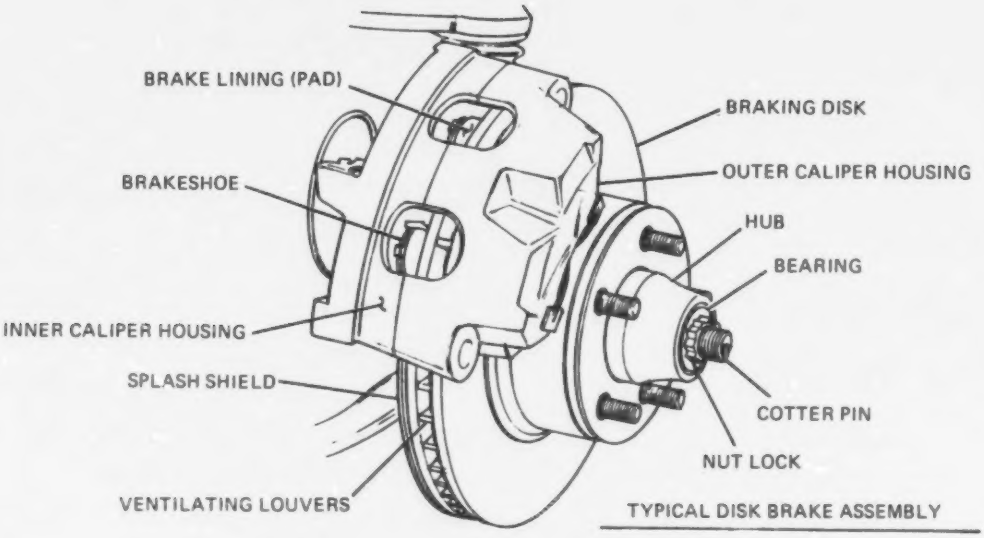
c. Lever Type. The lever-type self-adjusting system (C, fig. 34-10) is similar to the link type, in that it operates in the reverse direction only. While the link-type system uses linkage rods to perform the self-adjusting process, the lever type uses a stamped metal lever to engage the star wheel and an actuating link to connect to the anchor pin. The adjusting process is the same as the link-type system.

Section III. DISK BRAKE MECHANISMS

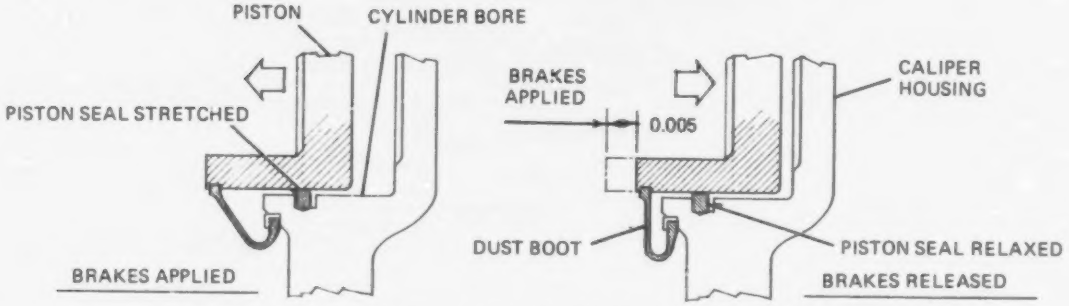
34-13. General. The disk brake system (fig. 34-11) is another form of brake system used in many modern vehicles. Like the drum system, the disk brake system is operated hydraulically and has rotating and nonrotating components. Disk brakes can be used on all four wheels or they can be mounted on the front wheels and used in conjunction with drum brakes, which are mounted in the rear. These configurations are very popular because the disk system is a very efficient brake system, it stays cool due to its open design, and is less prone to brake fade. The rotating member is in the form of a heavy round-shaped disk. The disk or rotor is attached to the wheel assembly and may be a solid or vented construction. The disk may be an integral part of the hub or detachable from the hub by the use of bolts. The clamp assembly or caliper is the stationary member in the system and usually is mounted to the spindle or splash shield to provide support. The caliper is fitted with one or more pistons that are actuated hydraulically by the fluid pressure developed in the brake system. Brake pads are designed to fit into the caliper and provide the frictional surface for the rotor to engage during braking.

a. Operating Principles. The disk brake, like the drum brake assembly, is operated by pressurized hydraulic fluid. The fluid, which is routed to the calipers through steel lines and flexible high-pressure hoses, develops its pressure in the master cylinder. Once the brake pedal is depressed, fluid enters the caliper and begins to force the piston(s) outward. This outward movement forces the brake pads against the moving rotor. Once this point is reached, the braking action begins. The greater the fluid pressure exerted on the piston(s) from the master cylinder, the tighter the brake pads will be forced against the rotor. This increase in pressure also will cause an increase in braking effect. As the pedal is released, pressure diminishes and the force on the brake pads is reduced. This allows the rotor to turn more easily. Some calipers allow the brake pads to rub lightly against the rotor at all times in the released position. Another design uses the rolling action of the piston seal to

625


BRAKE LINING (PAD)
BRAKING DISK
BRAKESHOE
OUTER CALIPER HOUSING
HUB
BEARING
INNER CALIPER HOUSING
SPLASH SHIELD
COTTER PIN
NUT LOCK
VENTILATING LOUVERS

TYPICAL DISK BRAKE ASSEMBLY


PISTON
CYLINDER BORE
BRAKES APPLIED
CALIPER HOUSING
PISTON SEAL STRETCHED
0.005
DUST BOOT
PISTON SEAL RELAXED
BRAKES APPLIED
BRAKES RELEASED

PISTON BEING RETRACTED

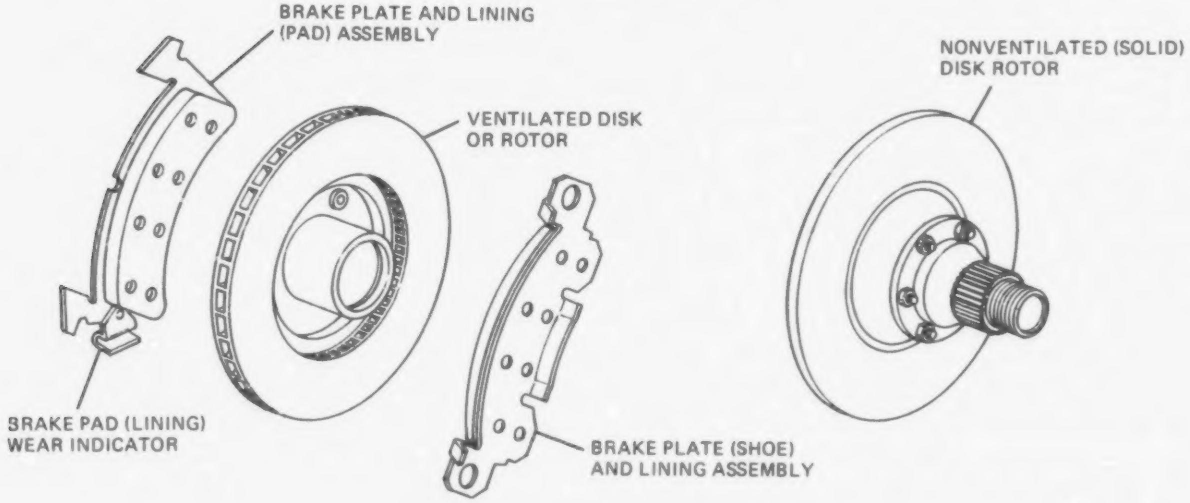

BRAKE PLATE AND LINING (PAD) ASSEMBLY
NONVENTILATED (SOLID) DISK ROTOR
VENTILATED DISK OR ROTOR
BRAKE PAD (LINING) WEAR INDICATOR
BRAKE PLATE (SHOE) AND LINING ASSEMBLY

Figure 34-11. Disk Brake Assembly.

TA233863

maintain a clearance of approximately 0.005 inch (fig. 34-11) when the brakes are released.

b. Comparison to Drum Brakes. Both the disk and drum brake assemblies used on modern vehicles are well-designed systems. Each system exhibits certain inherent advantages and disadvantages. The most important points of interest are discussed below. One major factor that must be discussed in automotive brakes, as well as all other brake systems, is the system's ability to dissipate heat. As discussed in paragraph 34-1, the byproduct of friction is heat. Because most brake systems use this concept to develop braking force, it is highly desirable for brake systems to dissipate heat as rapidly and efficiently as possible. The disk brake assembly, because of its open design, has the ability to dissipate heat faster than the drum brake. This feature makes the disk brake assembly less prone to brake fade due to a buildup of excess heat. The disk assembly also may have additional heat transfer qualities due to the use of a ventilated rotor. This type of rotor (fig. 34-11) has built-in air passages between friction surfaces to aid in cooling.

While the drum brake assembly requires an initial shoe-to-drum clearance adjustment and periodic checks, the disk brake assembly is self-adjusting and maintains proper adjustment at all times. The disk assembly automatically compensates for lining wear by allowing the piston in the caliper to move outward, thereby taking up excess clearance between pads and rotor (fig. 34-11). The disk system is fairly simplistic in comparison to the drum system. Due to this design, and its lack of moving parts and springs, the disk assembly is less likely to malfunction. Overhauling the disk brake assembly is faster because of its simplistic design. It also is safer due to the fact that the disk brake assembly is open and asbestos dust from linings is less apt to be caught in the brake assembly. Like brakedrums, rotors may be machined if excessive scoring is present. Rotors also are stamped with a minimum thickness dimension (fig. 34-11), which should not be exceeded. The drum brake assembly requires the drum be removed for lining inspection, while some disk pads have a built-in lining wear indicator (fig. 34-11) that produces an audible high-pitch squeal when linings are worn excessively. This harsh squeal is a result of the linings wearing to a point, allowing a metal indicator to rub against the rotor as the wheel turns. Because of its small frictional area, and lack of self-energizing and servo effect, the disk brake assembly requires the use of an auxiliary power booster to develop enough hydraulic pressure for satisfactory braking.

34-14. Floating Caliper. The floating caliper (fig. 34-12) is designed to move laterally on its mount. This movement allows the caliper to maintain a centered position with respect to the rotor. This design also permits the braking force to be applied equally to both sides of the rotor. The floating caliper usually is a one-piece solid construction and uses a single piston to develop the braking force. This type of caliper operates by pressurized hydraulic fluid like all other hydraulic calipers. The fluid under pressure first enters the piston cavity and begins to force the piston outward. As this happens, the brake pad meets the rotor. Additional pressure then forces the caliper assembly to move in the opposite direction of the piston, thereby forcing the brake pad on the opposite side of the piston to engage the rotor. As pressure is built up behind the piston, it then forces the brake pads tighter against the rotor to develop additional braking force.

34-15. Fixed Caliper. The fixed caliper (fig. 34-13) is mounted rigidly to the spindle or splash shield. In this design, the caliper usually is made in two pieces and has either two, three, or four pistons in use. The pistons, which may be made of cast iron, aluminum, or plastic, are provided with seals and dust boots and fit snugly in bores machined in the caliper. The centering action of the fixed caliper is accomplished by the pistons as they move in their bores. If the lining should wear unevenly on one side of the caliper, the excess clearance would be taken up by the piston simply by moving further out in its bore. As the brakes are applied, the fluid pressure enters the caliper on one side and is routed to the other through an internal passageway or an external tube connected to the opposite half of the caliper. As pressure is increased, the pistons force the brake pads against the rotors evenly and therefore maintain an equal amount of pressure on both sides of the rotor.

As discussed above, the fixed calipers use a multipiston design (fig. 34-13) to provide the braking force. The fixed calipers may be designed

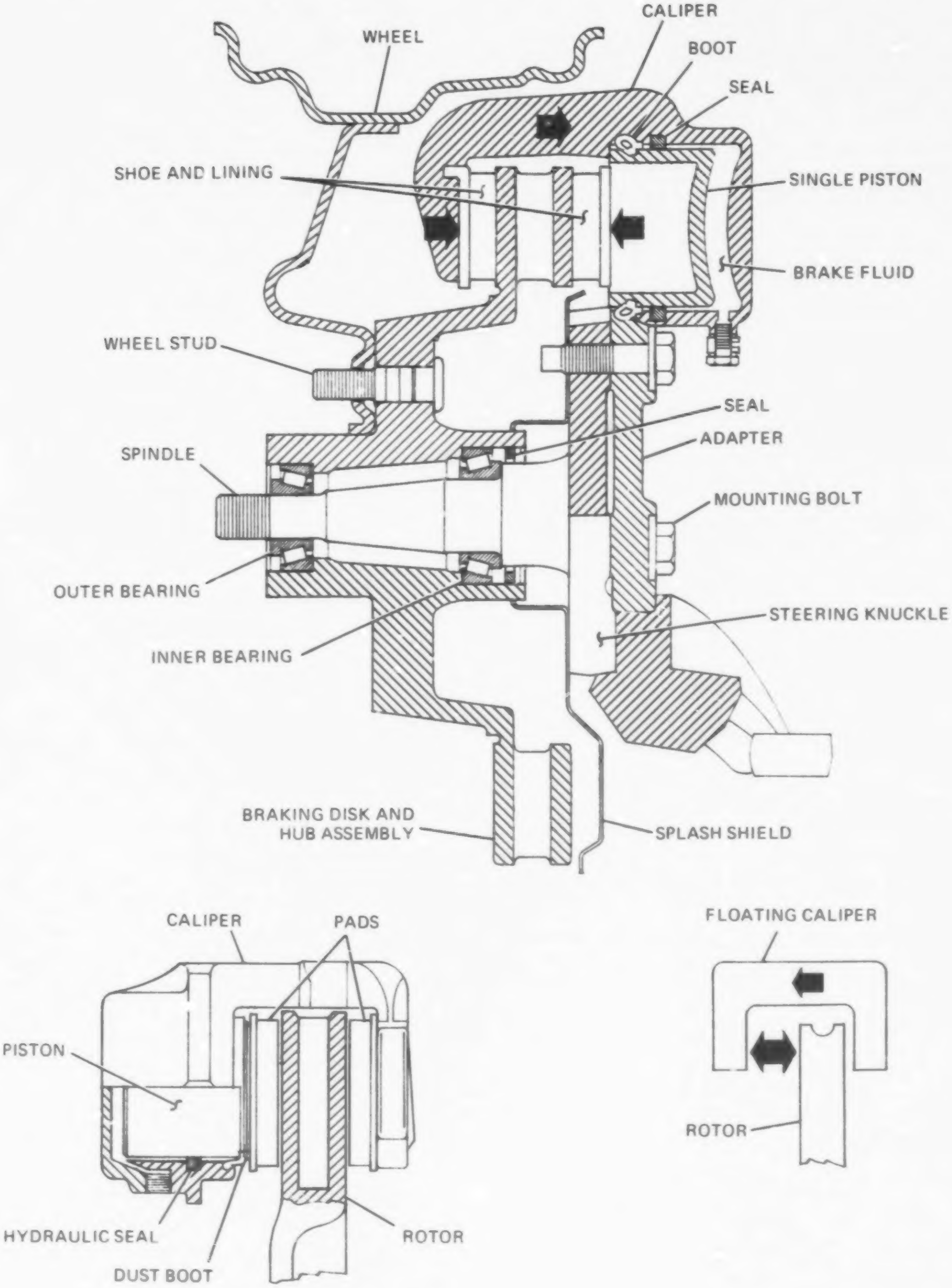

WHEEL
CALIPER
BOOT
SEAL
SHOE AND LINING
SINGLE PISTON
BRAKE FLUID
WHEEL STUD
SEAL
ADAPTER
SPINDLE
MOUNTING BOLT
OUTER BEARING
STEERING KNUCKLE
INNER BEARING
BRAKING DISK AND HUB ASSEMBLY
SPLASH SHIELD
CALIPER
PADS
PISTON
HYDRAULIC SEAL
DUST BOOT
ROTOR
FLOATING CALIPER
ROTOR

Figure 34-12. Floating Caliper.

TA233864

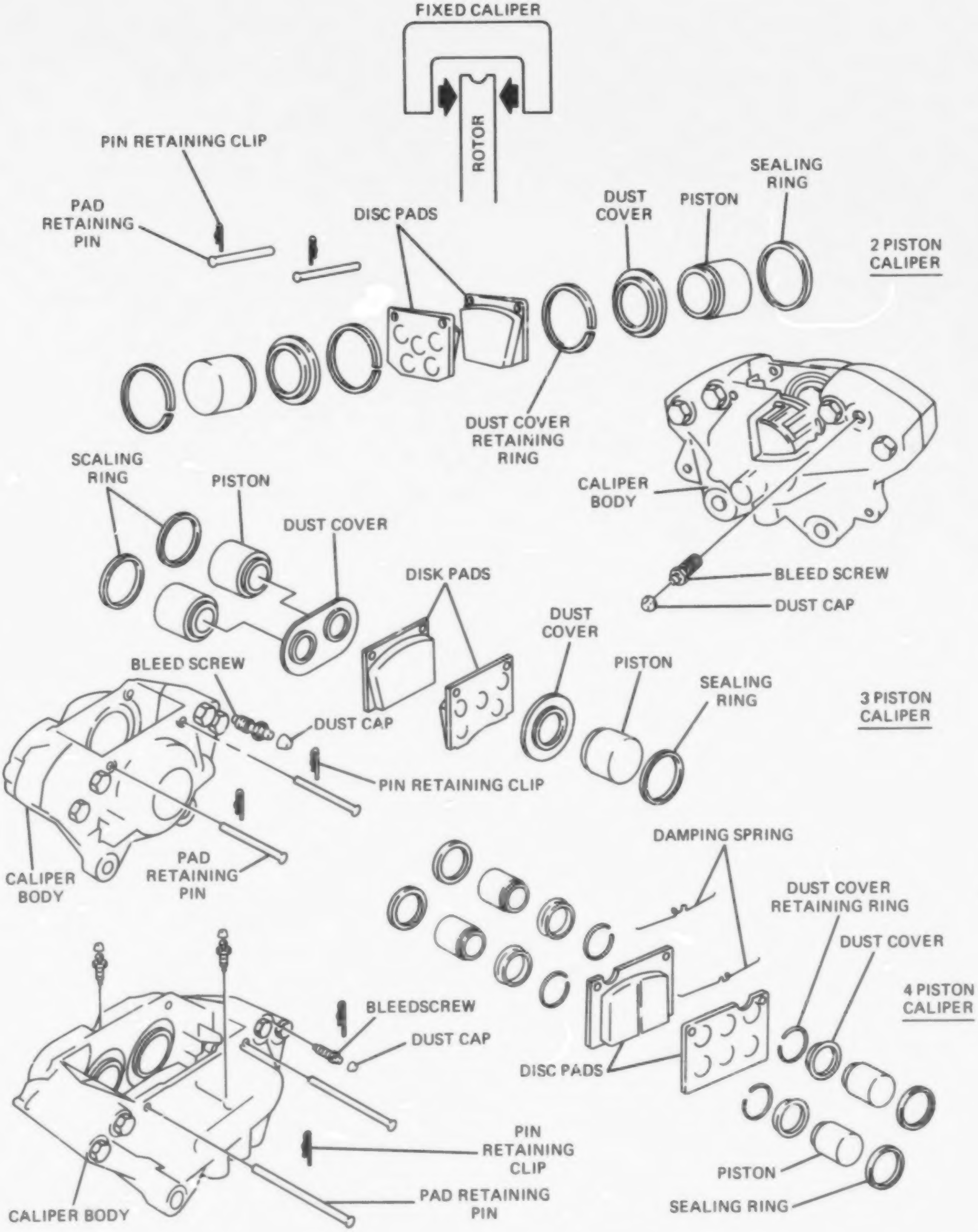

FIXED CALIPER
ROTOR
PIN RETAINING CLIP
PAD RETAINING PIN
DISC PADS
DUST COVER
PISTON
SEALING RING
2 PISTON CALIPER
DUST COVER RETAINING RING
CALIPER BODY
BLEED SCREW
DUST CAP
SCALING RING
PISTON
DUST COVER
DISK PADS
DUST COVER
PISTON
SEALING RING
3 PISTON CALIPER
BLEED SCREW
DUST CAP
PIN RETAINING CLIP
CALIPER BODY
PAD RETAINING PIN
DAMPING SPRING
DUST COVER RETAINING RING
DUST COVER
4 PISTON CALIPER
BLEEDSCREW
DUST CAP
DISC PADS
PIN RETAINING CLIP
PAD RETAINING PIN
CALIPER BODY
PISTON
SEALING RING

Figure 34-13. Fixed Multipiston Calipers.

TA233865

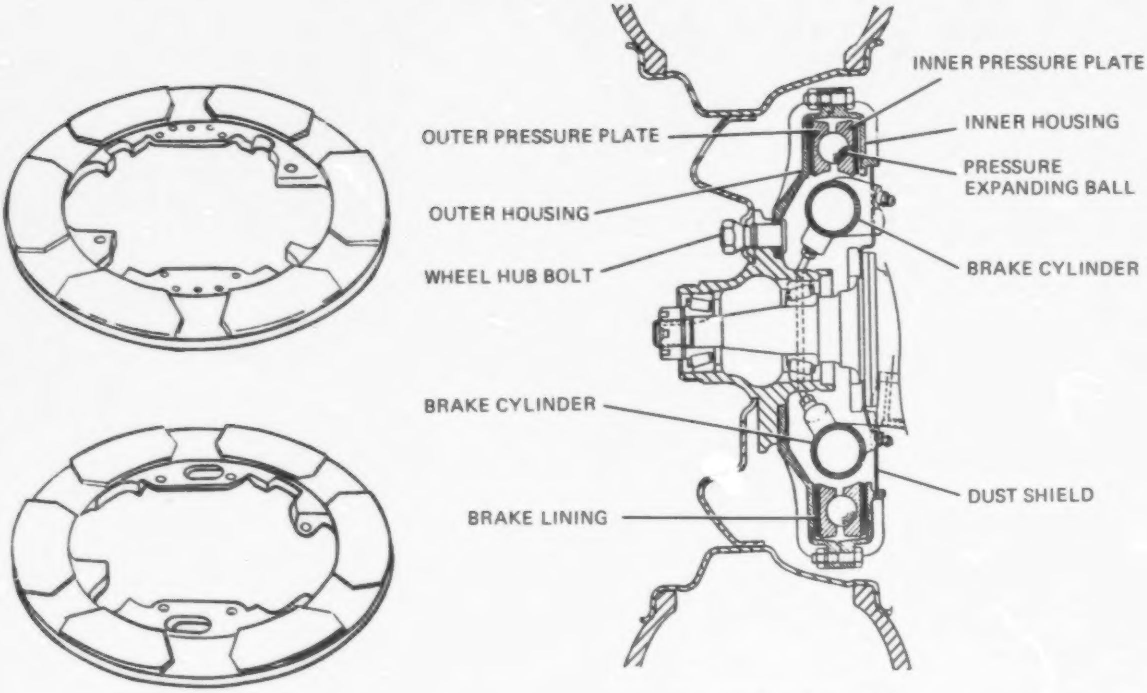
629

to use two, three, or four pistons. The dual-piston design provides a slight margin of safety over a single-piston floating caliper. In the event of a piston seizing in the caliper, the single-piston caliper would be rendered useless, while the dual-piston design would still have one working piston to restore some braking ability. The three- and four-piston design provides for the use of a larger brake lining. The brake force developed may now be spread over a larger area of the brake pad.

34-16. Self-Energizing Disk Brakes. There are two designs of the self-energizing disk brake system. Each one is discussed separately in the following text.

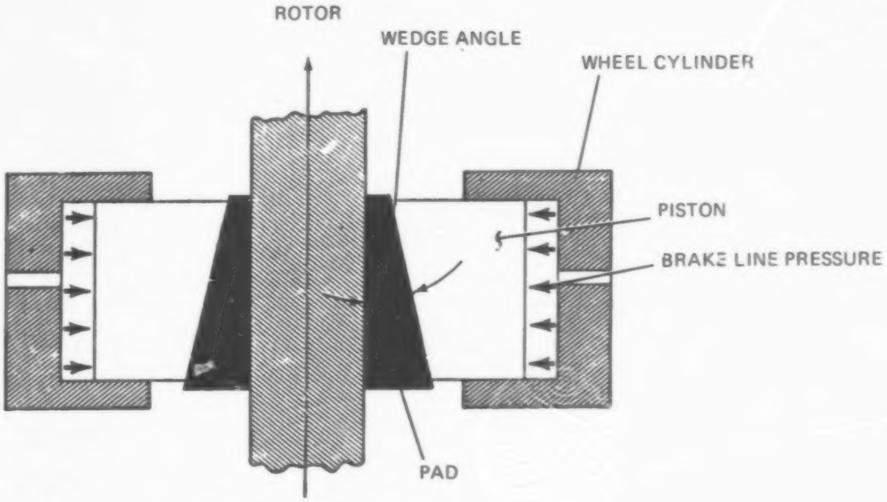
a. Rotating Plate Type. This type of self-energizing disk brake assembly (fig. 34-14) consists of a pair of pressure plates or flat rings faced on one side with a brake lining and assembled in a brake housing attached to the wheel. Six steel balls are positioned in a series arrangement in ramps between the two plates so that, when one plate is turned a few degrees, the balls ride up on the ramps and move the plates away from each other. This outward movement forces the plates into contact with the inner faces of the brake housing for braking action. The action is partially self-energizing because the plate that turns in the direction of motion tends to rotate further as it comes in contact with the inner face of the rotating brake housing. The frictional contact between the two tends to carry the outer plate around and produces a self-energizing action.

b. Wedge-Type Disk Brake. The basic wedge design of a self-energizing disk brake is illustrated in figure 34-14. The self-energizing effect is accomplished by means of a wedge-shaped disk brake pad. The friction force between pad and rotor tends to force the pad into the wedge-shaped piston, producing a self-energizing effect.


INNER PRESSURE PLATE
OUTER PRESSURE PLATE
INNER HOUSING
PRESSURE EXPANDING BALL
OUTER HOUSING
WHEEL HUB BOLT
BRAKE CYLINDER
BRAKE CYLINDER
DUST SHIELD
BRAKE LINING

ROTATING PLATE TYPE

BRAKE LINING SEGMENTS ON THE PRESSURE PLATE


ROTOR
WEDGE ANGLE
WHEEL CYLINDER
PISTON
BRAKE LINE PRESSURE
PAD

WEDGE TYPE DISK BRAKE

Figure 34-14. Self-Energizing Disk Brakes.

TA233866

Section IV. AUXILIARY BRAKE MECHANISMS

34-17. Contracting Transmission Brake. The contracting transmission brake generally is mounted between the output shaft of the transmission or transfer case (fig. 34-15). The rotating drum is splined or bolted to the transmission or transfer main shaft. The brake is designed for either forward or backward motion of the vehicle. For this reason, one end of the brake band is anchored just opposite that at which the operating force is applied. As the brakes are applied, the halves of the brake band wrap against the drum, preventing rotation in either direction. The mechanism for operating this brake usually is a simple bellcrank arrangement connected to a handbrake lever by a flexible cable. A spring disengages the brake band lining when the actuating force is released. The contracting transmission brake usually is not used in modern vehicles.

34-18. Disk Transmission Brake. The disk transmission brake (fig. 34-16) usually is mounted on the rear of the transmission or transfer case, or on a crossmember of the frame. The rotating member of the brake consists of a specially designed steel disk splined or bolted to the transmission output shaft. This disk has two faces that act as the rotating braking surface. Passages are arranged so that a large volume of air cools the braking surface when the disk is rotating. The shoes are supported on swinging brackets and are clamped against the disk faces by means of a cam lever arrangement. A spring removes the shoes from the disk faces when the hand or foot lever is released.

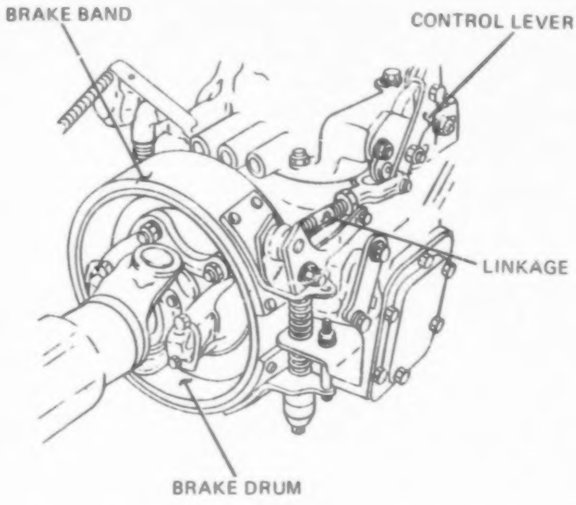


Figure 34-15. Contracting Transmission Brake.

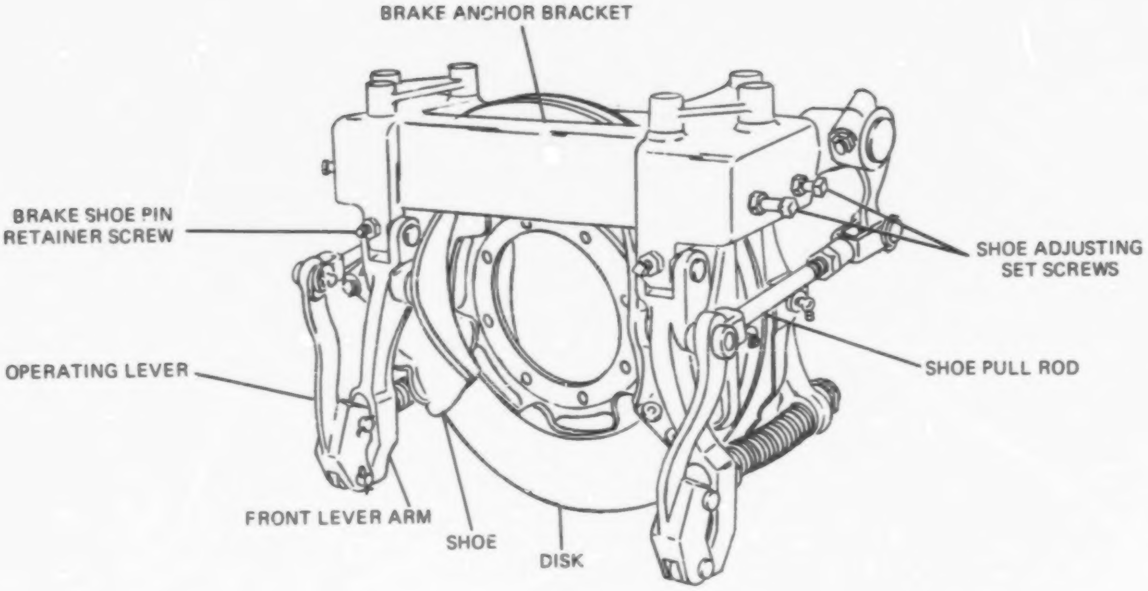
TA233867

34-19. Parking Brake. The parking brake usually is operated by an auxiliary foot pedal or hand lever located in the driver compartment. This brake mechanism is designed to keep the vehicle stationary when the operator is not present. There are different systems used for the disk and drum brake assemblies; each is discussed below.

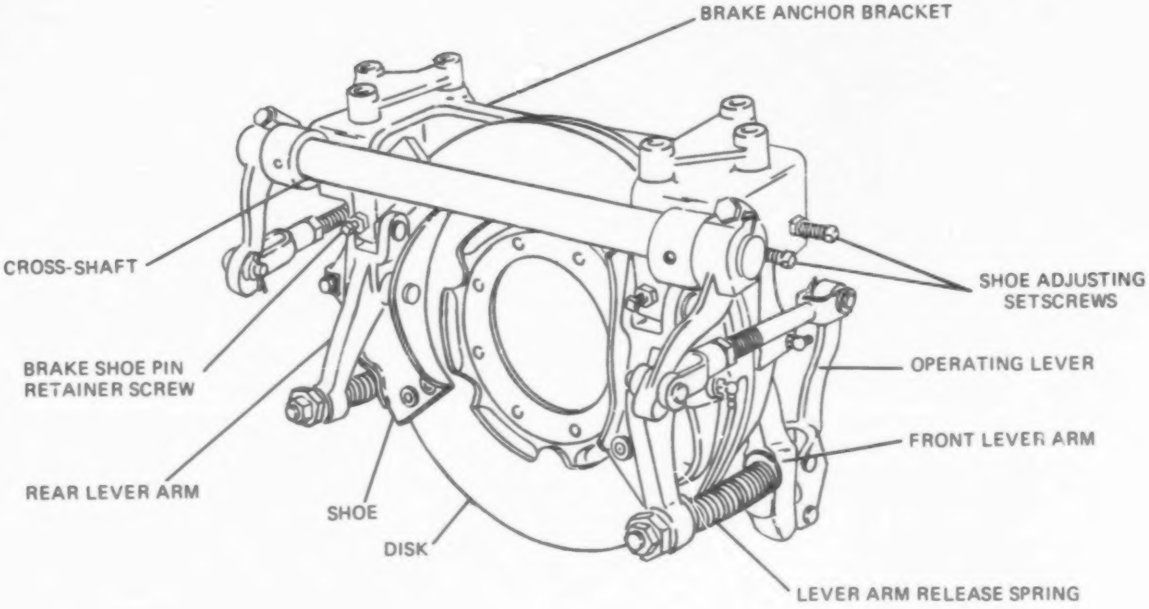
a. Disk Type. The disk brake system uses two basic types of parking brake systems (fig. 34-17). One system incorporates an integral parking brake mechanism in the caliper assembly. This system uses an actuator screw, operated by a lever and the parking brake cable, to apply the brake pads. As the parking brake is applied, the actuator screw is rotated, which forces the piston assembly and inner brake pad outward to meet the rotor. Further application shifts the caliper assembly and applies the outer brake pad. Another parking brake system used with disk brake systems uses two small internally expanding brakeshoes (fig. 34-17). The shoes are expanded against the internal section of the brake disk by an actuating lever operated by the parking brake cable.

b. Drum Brake Type. The drum brake system uses one basic parking brake assembly (fig. 34-17). This configuration uses a parking brake lever that is activated by a flexible cable routed to both rear wheels. As the parking brake is applied, the parking brake lever pivots on the top of the secondary brakeshoe. This action allows the parking brake strut to move forward and apply the primary shoe. Further application now pivots the parking brake lever on the parking brake strut, thereby forcing the secondary shoe against the brakedrum.

34-20. Advantages and Disadvantages of Transmission Brakes. Transmission and transfer assembly brakes theoretically are more efficient than wheel brakes because the braking effort is multiplied by the final drive ratio, and their braking action is equalized perfectly through the differential. However, they put a severe strain on the power transmission system, and they are not


BRAKE ANCHOR BRACKET
BRAKE SHOE PIN RETAINER SCREW
SHOE ADJUSTING SET SCREWS
OPERATING LEVER
SHOE PULL ROD
FRONT LEVER ARM
SHOE
DISK

FRONT VIEW


BRAKE ANCHOR BRACKET
CROSS-SHAFT
SHOE ADJUSTING SETSCREWS
BRAKE SHOE PIN RETAINER SCREW
OPERATING LEVER
FRONT LEVER ARM
REAR LEVER ARM
SHOE
DISK
LEVER ARM RELEASE SPRING

REAR VIEW

Figure 34-16. Disk Transmission Brake.

TA233868

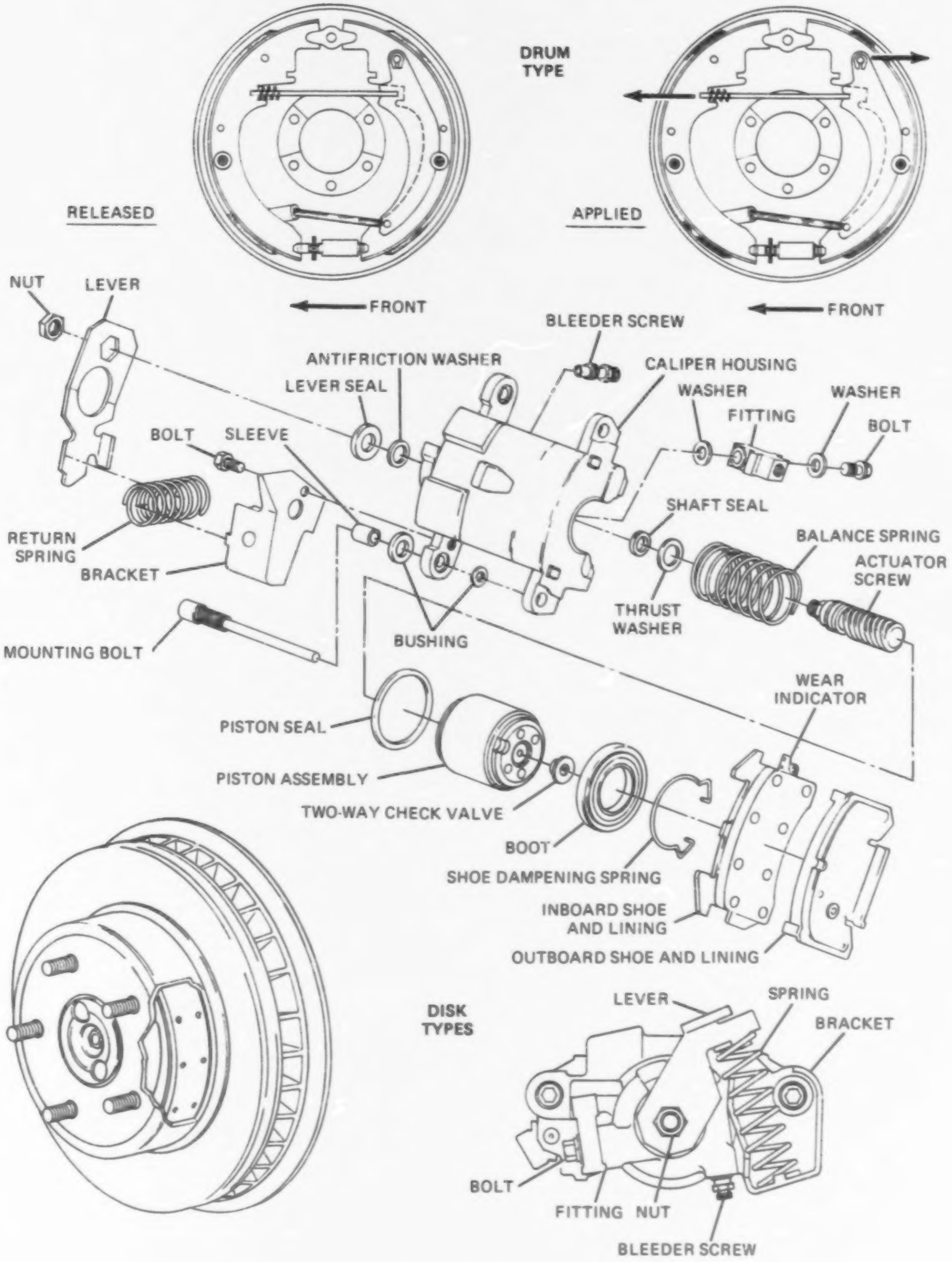

DRUM TYPE
RELEASED
APPLIED
FRONT
FRONT
NUT
LEVER
BLEEDER SCREW
ANTIFRICTION WASHER
CALIPER HOUSING
LEVER SEAL
WASHER
WASHER
FITTING
BOLT
BOLT
SLEEVE
SHAFT SEAL
RETURN SPRING
BALANCE SPRING
ACTUATOR SCREW
BRACKET
THRUST WASHER
BUSHING
MOUNTING BOLT
WEAR INDICATOR
PISTON SEAL
PISTON ASSEMBLY
TWO-WAY CHECK VALVE
BOOT
SHOE DAMPENING SPRING
INBOARD SHOE AND LINING
OUTBOARD SHOE AND LINING
DISK TYPES
LEVER
SPRING
BRACKET
BOLT
FITTING
NUT
BLEEDER SCREW

Figure 34-17. Parking Brake Configurations.

TA233869

positive in performance for they do not prevent the action of the differential assembly from taking place. Therefore, in some conditions, the vehicle may move while the brake is applied.

Section V. MECHANICAL BRAKE SYSTEM

34-21. Means of Actuation. The energy supplied by the operator's foot in pushing down on the brake pedal is transferred to the brake mechanism on the wheels by various means. A mechanical hookup has been used since the earliest motor vehicles, but hydraulic pressure is used most extensively at the present time. Mechanically operated braking systems are obsolete on today's automobiles, but these systems may be used for a portion of the braking systems in many vehicles.

34-22. Hookup.

a. *Cross-Shaft.* In a mechanical braking system, the force applied to the pedal is transmitted to the brakes by means of rods and cables. The mechanical linkage may be arranged in various ways, but its operation is essentially the same. In order to have all the wheel brakes applied uniformly, a cross-shaft is provided near the center of the vehicle frame, on which the levers connected to the rods and cables leading to the wheel brakes are mounted. The brake pedal also is connected to a lever on the cross-shaft (fig. 34-18). When the pedal is depressed, the cross-shaft (fig. 34-18) is turned so that levers on the top of the shaft are turned backward and those on the bottom of the shaft forward. By connecting the front brake rods to the levers on the top of the shaft, and the rear brake rods to the levers on the bottom of the shaft, all the brake rods are pulled together and the four wheel brakes are applied at the same time. The usual practice in mechanical systems has been to link the handbrake to the footbrake so that both operate the same braking units. With such an arrangement, the handbrake linkage incorporates an overrunning slot in the handbrake pull rod where it is connected to a lever on the cross-shaft. This allows the pedal linkage to operate without interference from the hand lever. Both controls may be operated independently by also incorporating an overrunning slot in the footbrake linkage.

b. *Two Cross-Shafts.* In some mechanical brake arrangements, two cross-shafts (fig. 34-18) are provided, so that the handbrake is applied to the shoes in the rear wheels only. The front and rear cross-shafts are connected together by an interconnecting rod joined to a lever on each shaft. An overrunning slot must be provided on the interconnecting rod (fig. 34-18) and the handbrake pull rod if the rear wheel brakes only are to be applied by the brake hand lever. Some braking systems incorporate additional shoes on the rear wheels for the handbrake, in which case the handbrake has its own cross-shaft and hookup, and is in no way connected with the foot or service brakes.

c. *Front Wheel Control.* The hookup of the brake rods to the front wheels must be designed to allow the wheels to turn without locking in any position. If the front wheels lock, steering is destroyed. One means of controlling the front wheels is the use of the brake rod attached to a camshaft, with a small universal joint above the steering knuckle pivot. A more popular and satisfactory method employs a flexible steel cable connecting the end of the brake rod to the brake camshaft lever (fig. 34-18). Because of the flexibility of the cable and its sheath, motion of the wheel does not affect tension on the cable. Flexible steel cables also may be used advantageously on the rear wheels because of the vibration of the wheels when traveling over the road. On some braking systems, the pressure on the wheel brakes is distributed evenly by various types of equalizers. Equalizers are designed to take up all the slack in the hookup to each brake so that all brakes will be applied at the same time. This prevents the possibility of too much pressure being applied to any one brake, which would lock that wheel and probably make the vehicle skid. One of the main reasons why the mechanical braking system has been supplanted is the difficulty of maintaining equal pressure on all brakes.

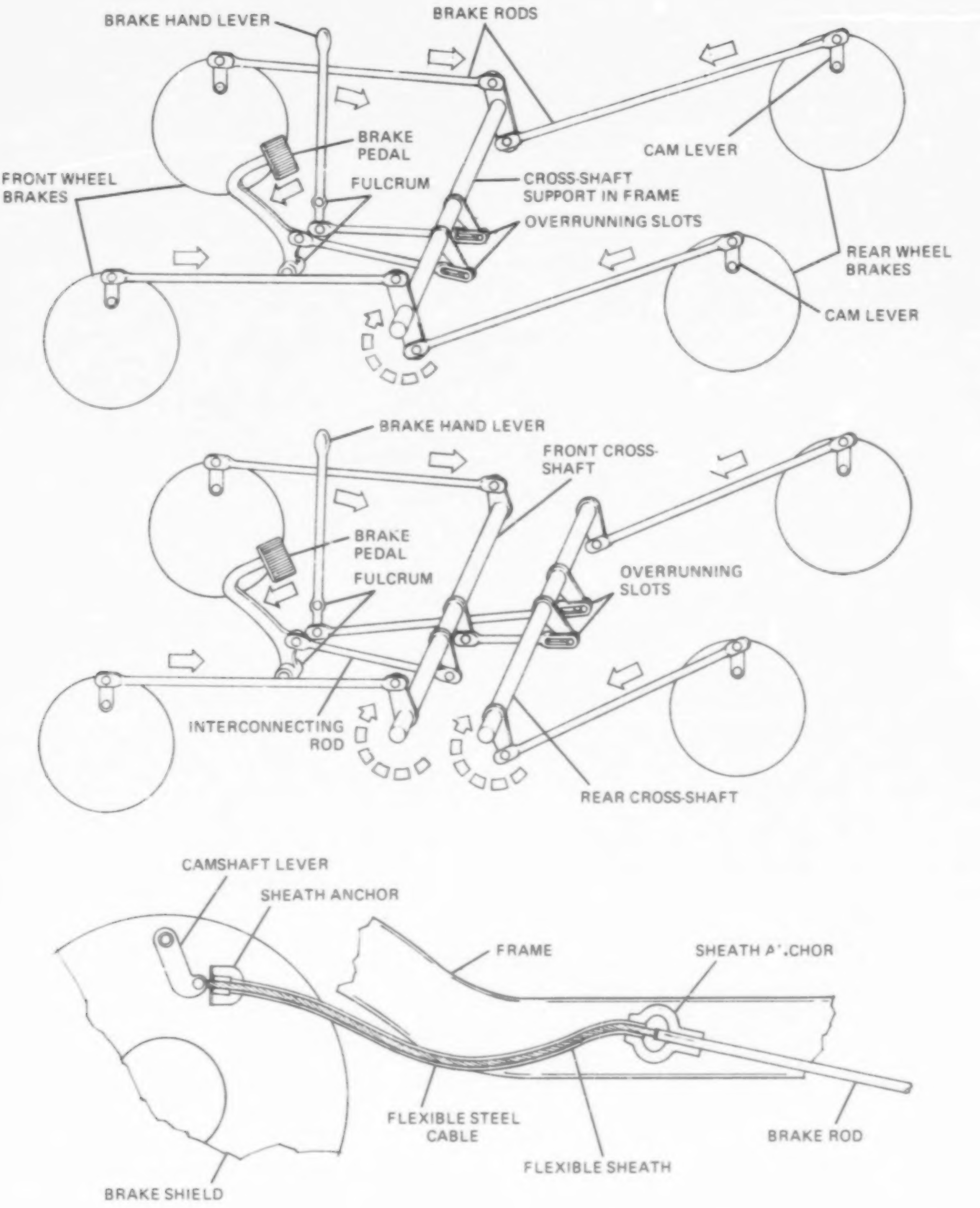

BRAKE HAND LEVER
BRAKE RODS
BRAKE PEDAL
FULCRUM
CROSS-SHAFT SUPPORT IN FRAME
CAM LEVER
FRONT WHEEL BRAKES
OVERRUNNING SLOTS
REAR WHEEL BRAKES
CAM LEVER
BRAKE HAND LEVER
FRONT CROSS-SHAFT
BRAKE PEDAL
FULCRUM
OVERRUNNING SLOTS
INTERCONNECTING ROD
REAR CROSS-SHAFT
CAMSHAFT LEVER
SHEATH ANCHOR
FRAME
SHEATH ANCHOR
FLEXIBLE STEEL CABLE
FLEXIBLE SHEATH
BRAKE ROD
BRAKE SHIELD

Figure 34-18. Mechanical Brake System.

TA233870

6.36

Section VI. HYDRAULIC BRAKE SYSTEM

34-23. Principles of the Hydraulic System. In hydraulic braking systems, the pressure applied at the brake pedal is transmitted to the brake mechanism by a liquid. To understand how pressure is transmitted by a hydraulic braking system, it is necessary to understand the fundamentals and principles of hydraulics. Hydraulics is the study of liquids in motion, or the pressure exerted by liquids conveyed in pipes or conduits.

One well-known hydraulic principle is that liquids cannot be compressed under ordinary pressures. This may be demonstrated by placing a weight on top of a piston fitted to a jar (A, fig. 34-19). The force of the weight does not change the level of the liquid, therefore, it does not diminish the volume or compress the liquid.

Another well-known hydraulic principle is Pascal's law (para 20-2), which states that force exerted at any point upon a confined liquid is distributed equally through the liquid in all directions. That is, if a total force of 20 pounds, including piston and weight, is placed upon liquid in a jar, and if the piston in the jar has an area of 5 square inches, the unit hydraulic pressure is increased by 20/5, or 4 psi. This is illustrated in B, figure 34-19. A gage inserted at any point in the jar will indicate the same pressure of 4 psi, because the liquid transmits the pressure equally throughout the jar.

Use of these hydraulic principles may be illustrated by interconnecting two jars, of the same diameter, containing liquid (C, fig. 34-19). If a force is exerted on a piston in one jar, as in the left jar in C, figure 34-19, a piston placed in the other jar will receive the same amount of force, due to the transmission of pressure by the liquid. When the areas of the two pistons are equal, moving one piston produces identical movement in the other piston because the liquid is not compressible and therefore maintains the same volume.

By connecting one jar with another jar that has twice the diameter and therefore four times the area of the first jar (D, fig. 34-19), the results are somewhat different, although the same basic facts apply. When a force is exerted on the piston in the small jar, the piston in the large jar will receive four times as much force because the hydraulic pressure acts on four times the area. Because the liquid will always occupy the same volume, the large piston will move one-fourth as far as the small piston. Thus, a mechanical advantage is obtained very similar to that obtained from a simple lever.

With four jars, all of the same diameter, connected to a central jar (E, fig. 34-19), an approximation of the action in four-wheel brakes is obtained. A force exerted on the piston in the central jar will be transmitted to each of the other jars so that the piston in each will receive an identical force but will move only one-fourth as far as the central piston.

If the four jars have a larger diameter than the central jar, the total pressure on each of the four pistons is greater than that applied to the central one, and each of the four pistons moves less than one-fourth as far as the central piston. Hydraulic brake systems operate in such a manner.

34-24. Operation. In a hydraulic brake system, the force is applied to a piston in a master cylinder that corresponds to the central jar (fig. 34-20). The brake pedal operates the piston by linkage. Each wheel brake is provided with a cylinder fitted with opposed pistons connected to the brakeshoes.

The brake pedal, when depressed, moves the piston within the master cylinder, forcing the brake liquid or fluid from the master cylinder through tubing and flexible hose into the four wheel cylinders. A diagram of a hydraulic brake system is shown in figure 34-20.

The brake fluid enters each of the wheel cylinders between opposed pistons, making the pistons move the brakeshoes outward against the brakedrum. As pressure on the pedal is increased, greater hydraulic pressure is built up within the wheel cylinders and, consequently, greater force is exerted against the ends of the shoes.

When pressure on the pedal is released, retracting springs on the brakeshoes return the wheel cylinder pistons to their release position, forcing the brake fluid back through the flexible hose and tubing to the master cylinder.

637

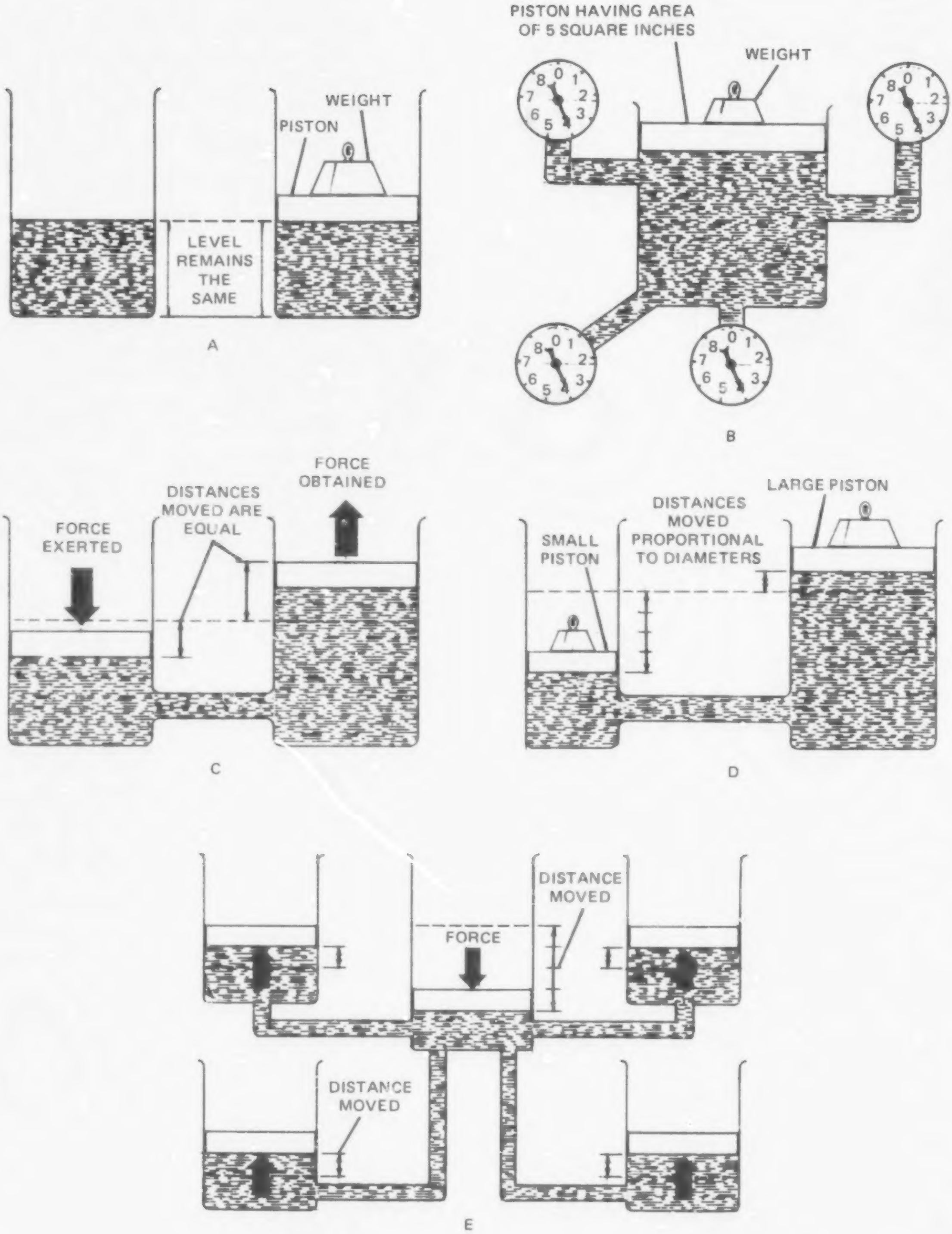

PISTON
WEIGHT
LEVEL REMAINS THE SAME
A
PISTON HAVING AREA OF 5 SQUARE INCHES
WEIGHT
B
FORCE EXERTED
DISTANCES MOVED ARE EQUAL
FORCE OBTAINED
C
SMALL PISTON
DISTANCES MOVED PROPORTIONAL TO DIAMETERS
LARGE PISTON
D
DISTANCE MOVED
FORCE
DISTANCE MOVED
E

Figure 34-19. Principles of the Hydraulic System.

TA233871

638

BEST COPY AVAILABLE

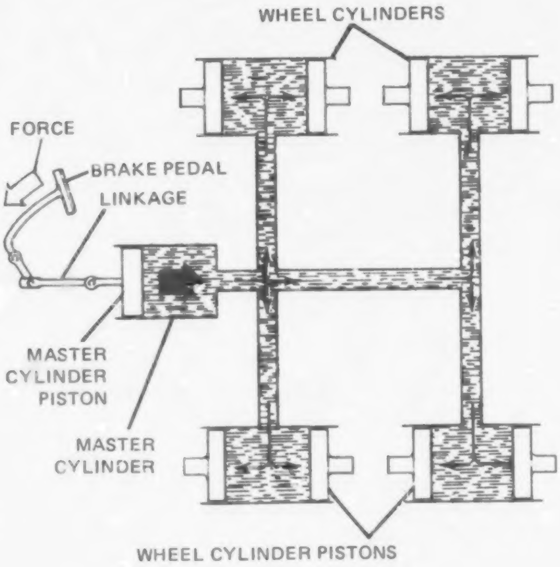


Figure 34-20. Diagram of Hydraulic Brake System.

34-25. Master Cylinder. The master cylinder is the primary unit in the brake system that converts the force of the driver's foot into fluid pressure to operate the wheel brake cylinders. The master cylinder housing is an aluminum or iron casting that may have an integral reservoir, in which case, it usually is made of the same material the cylinder is made of, or a detachable nylon or steel reservoir. The reservoir carries sufficient reserve fluid to allow for expansion and contraction of brake fluid and brake lining wear. The reservoir is filled at the top and is well sealed by a removable filler cap containing a vent. The master cylinder usually is mounted to the firewall, which allows for easy inspection and service and is less prone to dirt and water.

a. Piston. The piston (fig. 34-21) is a long, spoollike member with a rubber secondary cup seal at the outer end and a rubber primary cup that acts against the brake liquid just ahead of the inner end. This primary cup is kept against the end of the piston by a return spring. A steel stop disk, held in the outer end of the cylinder by a retainer spring, acts as a piston stop. A rubber boot covers the piston end of the master cylinder to prevent dust and other foreign matter from entering it. This boot is vented to prevent air from being compressed within it.

b. Check Valve. A combination inlet and outlet check valve (fig. 34-21) is in the head of the master cylinder, held in place by the piston return spring. The check valve consists of a rubber valve cup in a steel valve case. This assembly rests on a rubber valve seat that fits in the end of the cylinder. In some designs, the check valve consists of a spring-operated outlet valve seated on a valve cage, rather than a rubber-cup outlet valve. The principle of operation is the same. The piston return spring normally holds the valve cage against the rubber valve seat to seal the brake fluid in the brake line.

c. Dual Master Cylinder. The dual master cylinder (fig. 34-21) contains two brake circuits that are separated hydraulically. The individual brake systems may be designed to divide the system front to rear, diagonally, or in various other fashions. If a brake fluid leak develops in one circuit, the other circuit still provides emergency stopping capability. As the brake pedal is depressed under normal operating conditions, it forces the primary piston forward to cover the primary compensating port. At this time, the primary chamber is sealed and direct hydraulic pressure is transmitted to the secondary piston. As the brake pedal continues to travel, the secondary piston covers the compensating port. Further application of the brake pedal develops the pressure required to apply the brake components. Should a leak develop in the primary circuit, the brake system would not be rendered useless. During the application of the brakes, the primary piston would continue to move forward, unable to build pressure due to the malfunction. Approximately halfway through its maximum stroke, the primary piston contacts the secondary piston. Further application of the brake would force the secondary piston forward to develop pressure in the secondary system, which would allow for braking action to take place in two wheels. Should the secondary circuit fail, braking for the other two wheels would still be available. The primary piston would move forward and cover the primary compensating port as before. Because of the rupture in the secondary circuit, the secondary or floating piston would be moved to its extreme stop by the force of the return spring. Further application of the brake would develop enough pressure in the primary circuit to apply the brakes connected to this circuit, therefore allowing the vehicle to maintain some stopping ability.

639

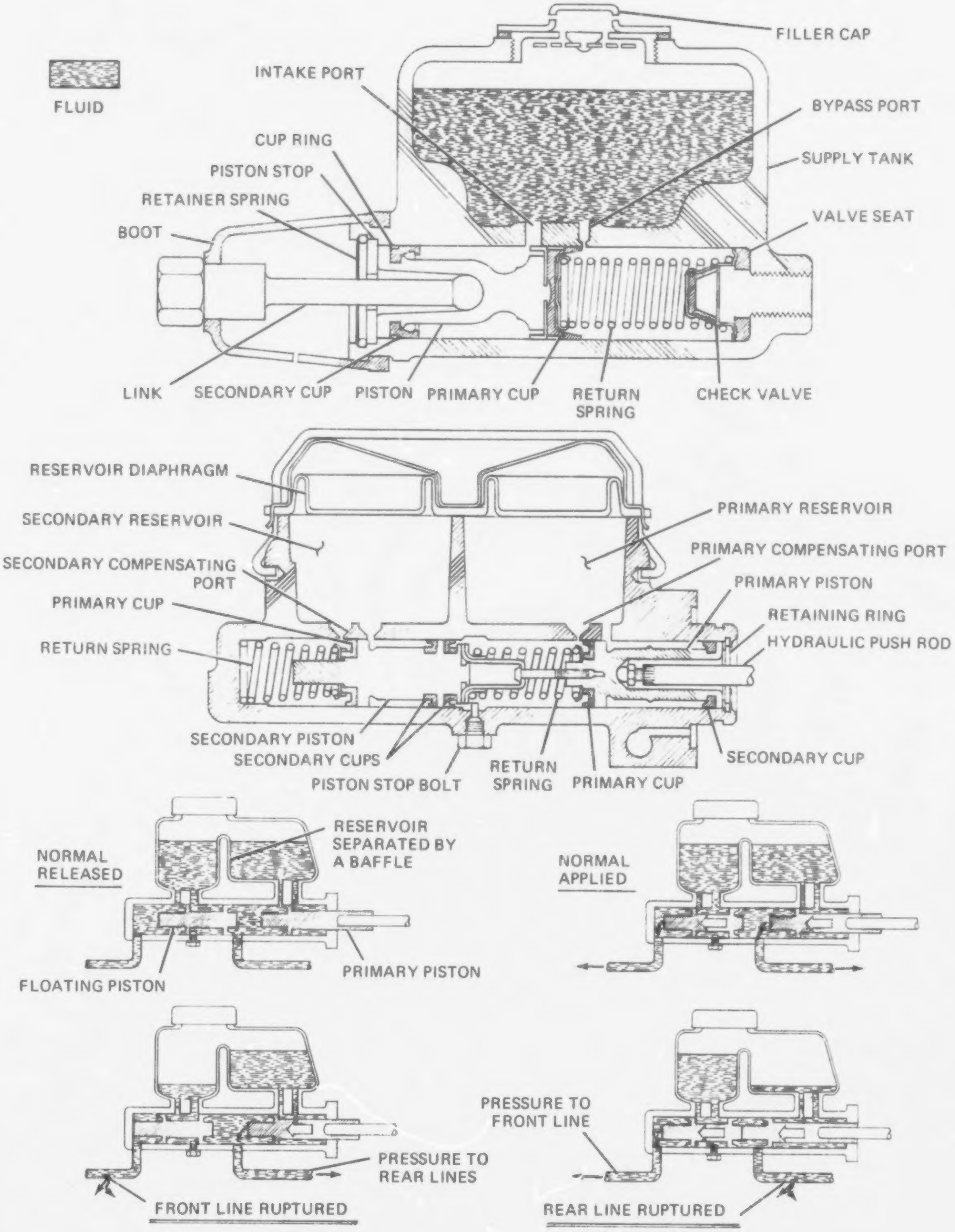
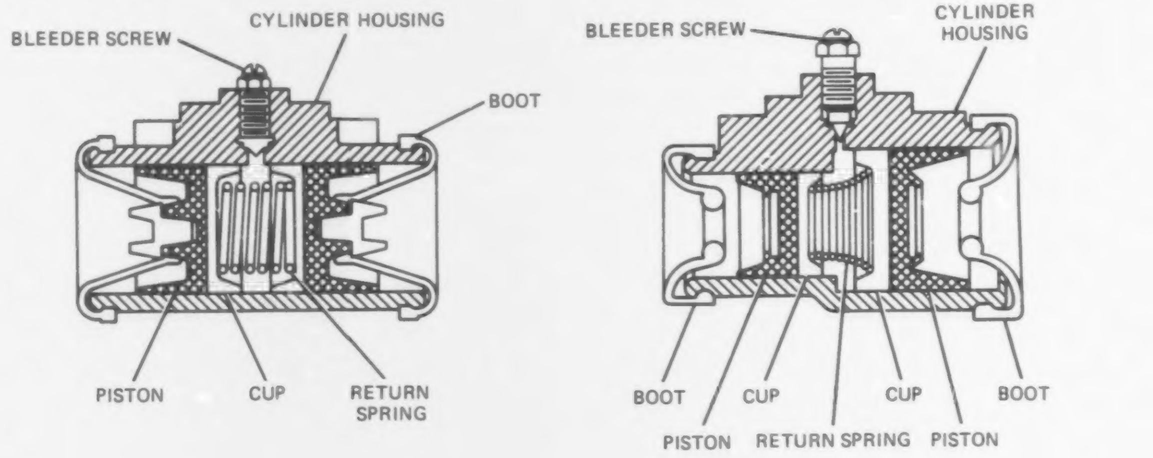

FLUID
INTAKE PORT
FILLER CAP
BYPASS PORT
CUP RING
SUPPLY TANK
PISTON STOP
RETAINER SPRING
VALVE SEAT
BOOT
LINK
SECONDARY CUP
PISTON
PRIMARY CUP
RETURN SPRING
CHECK VALVE
RESERVOIR DIAPHRAGM
SECONDARY RESERVOIR
PRIMARY RESERVOIR
SECONDARY COMPENSATING PORT
PRIMARY COMPENSATING PORT
PRIMARY PISTON
PRIMARY CUP
RETAINING RING
RETURN SPRING
HYDRAULIC PUSH ROD
SECONDARY PISTON
SECONDARY CUPS
SECONDARY CUP
PISTON STOP BOLT
RETURN SPRING
PRIMARY CUP
NORMAL RELEASED
RESERVOIR SEPARATED BY A BAFFLE
NORMAL APPLIED
FLOATING PISTON
PRIMARY PISTON
PRESSURE TO FRONT LINE
PRESSURE TO REAR LINES
FRONT LINE RUPTURED
REAR LINE RUPTURED

Figure 34-21. Master Cylinder and Components.

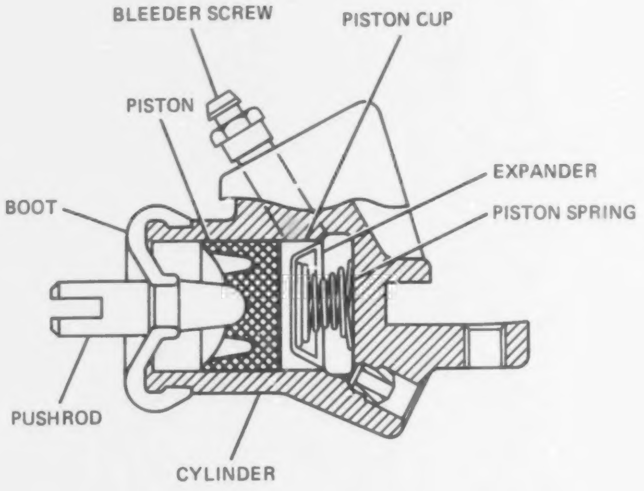
TA233873

34-26. Wheel Cylinder. The wheel cylinder (A, fig. 34-22) changes hydraulic pressure to the mechanical force that pushes the brakeshoes against the drums. The wheel cylinder housing is a casting mounted on the brake backing plate. Inside the cylinder are two pistons that are moved in opposite directions by hydraulic pressure and which, at the same time, push the shoes against the drum. The pistons or piston stems are connected directly to the shoes. Rubber piston cups fit tightly in the cylinder bore against each piston to prevent the escape of brake liquid. There is a light spring between the cups to keep them in position against the pistons. The open ends of the cylinder are fitted with rubber boots to keep out foreign matter. Brake fluid enters the cylinder


BLEEDER SCREW
CYLINDER HOUSING
BOOT
PISTON
CUP
RETURN SPRING
BLEEDER SCREW
CYLINDER HOUSING
BOOT
CUP
CUP
BOOT
PISTON
RETURN SPRING
PISTON

A. WHEEL CYLINDER – CROSS-SECTIONAL VIEW

B. STEPPED WHEEL CYLINDER – CROSS-SECTIONAL VIEW


BLEEDER SCREW
PISTON CUP
PISTON
EXPANDER
BOOT
PISTON SPRING
PUSHROD
CYLINDER

C. SINGLE-PISTON WHEEL CYLINDER

Figure 34-22. Wheel Cylinder Configurations.

TA233874

from the brake line connection between the pistons. At the top of the cylinder, between the pistons, is a bleeder hole through which air is released when the system is filled with brake fluid. A stepped wheel cylinder (B, fig. 34-22) is used to compensate for faster rate of wear on the front shoe than on the rear shoe, due to self-energizing action. By using a larger piston for the rear shoe, the shoe receives more pressure to offset the self-energizing action on the front shoe. This requires a stepped wheel cylinder with two bore sizes. If it is desired that both shoes be independently self-energizing, especially on the front wheels, it is necessary to have two wheel cylinders, one for each shoe. Each cylinder has a single piston (C, fig. 34-22), and is mounted on the opposite side of the brake backing plate from the other cylinder. Such an arrangement is shown in figure 34-9.

34-27. Hill Holder. The hill holder provides greater ease of vehicular control on hills and in traffic. The device is connected to the clutch pedal and keeps the brakes applied as long as the clutch pedal is depressed when the car is on an upgrade, even after the brake pedal is released. The driver then is able to use his or her right foot for the accelerator pedal.

34-28. Brake Lines. The brake lines transmit fluid under pressure from the master cylinder to the wheel cylinders. High-quality double thick steel tubing (fig. 34-23) is used where no flexing is involved. The tubing also is copper plated and coated with lead to prevent rust and corrosion. Due to the relative movement of the suspension, a high-pressure hose (fig. 34-23) is used to transmit fluid to each front wheel brake assembly and to the components on the rear axle(s). Mounting brackets also are used where flex hoses connect to solid hoses. The mounting brackets help hold the assemblies secure and reduce vibration, which may cause metal fatigue.

34-29. Brake Fluid. Hydraulic brake fluid is the liquid medium in the brake system used to transmit fluid motion and pressure to the wheel brake components. The hydraulic brake fluid used in today's modern vehicles must have some important properties; the most important are discussed below. The fluid must remain a liquid during all operating temperatures. The boiling point of the fluid must be well above the temperatures encountered during the most severe brake application on the hottest day and also maintain an even viscosity at extreme cold temperatures. The brake fluid must be able to absorb and hold moisture and also act as a lubricant.

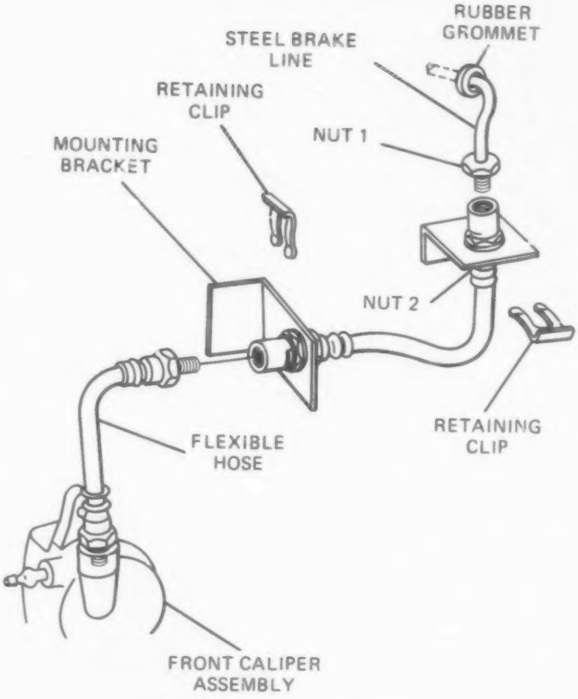


Figure 34-23. Brake Lines.

a. Standard Fluid. Standard brake fluid is composed chiefly of equal parts of alcohol and caster oil. This combination of fluids worked well under normal conditions but boiled easily and became a vapor under heavy-duty application. Standard fluid also tends to separate into components when exposed to low temperatures. The increasing requirements of brake fluid led to the development of silicone brake fluid.

b. Silicone Brake Fluid. After 40 years of research and development, a brake fluid that was acceptable under extreme operating conditions was developed. This fluid achieved low water pickup and good corrosion protection. The fluid also provides good lubrication qualities and rubber compatibility. Silicone brake fluid has been used in all military vehicles since the end of 1982.

TA233875

642

34-30. Proportioning Valve. Due to the lack of self-energizing and servo effect, disk brakes operate at higher line pressures than drum brakes. For this reason, a proportioning valve is used. The proportioning valve is designed to limit the amount of pressure routed to the rear brakes when a combination of disk brakes and drum brakes are used on a vehicle. By limiting pressure to the rear wheels, the chances of rear wheel lockup are reduced during a hard stop.

34-31. Limiting Valve. The limiting valve closes off one brake line at a certain brake line pressure and holds the pressure constant regardless of increases in supply pressure to the valve. Increases in brake fluid requirement in the closed-off brake line due to heat expansion or contraction are adjusted automatically by the valve through a brief reopening of the valve to supply pressure. Once the pressure adjustment is completed, the valve automatically closes off the brake line with the limited pressure.

Section VII. POWER BRAKING SYSTEMS

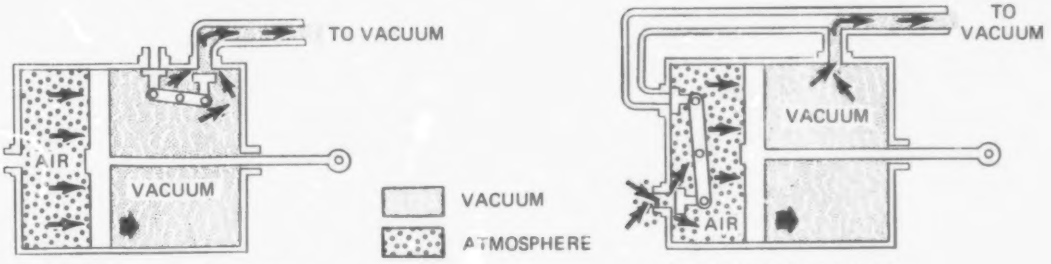
34-32. Construction. Power braking systems are designed to reduce the effort required to depress the brake pedal when stopping or holding a vehicle stationary. Most power brake systems use the difference in pressure between intake manifold vacuum and atmospheric pressure to develop the additional force required to decrease brake pedal pressure. When a vehicle is powered by a diesel engine, the absence of intake manifold vacuum requires the use of an auxiliary vacuum pump. This type of pump usually is driven by the engine or by an electric motor. The vacuum power booster may be classified into two basic categories: vacuum suspended and atmospheric suspended (A, fig. 34-24). The vacuum-suspended power booster utilizes intake manifold vacuum that acts on both sides of the diaphragm in the released position. When the brakes are applied, one side of the diaphragm is vented to atmosphere. This causes the diaphragm to move in the direction of the lowest pressure. This movement develops a force that is directed on the push rod of the master cylinder to aid in reducing brake pedal pressure. The atmospheric-suspended booster allows atmospheric pressure to act on the diaphragm in the released position. When the brakes are applied, the side of the diaphragm toward the master cylinder is subjected to controlled vacuum,therefore moving the diaphragm in that direction, which assists in applying the brakes. The power brake unit functions during three phases of braking application: brakes released, brakes being applied, and brakes holding. A typical vacuum-suspended power brake unit (B, fig. 34-24) will be used to describe these operations.

a. Released Position (C, Fig. 34-24). With the brakes fully released, and engine operating, the rod and plunger return spring moves the valve operating rod and valve plunger to the right. As this happens, the right end of the valve plunger is pressed against the face of the poppet valve, which in turn, closes off the atmospheric port. With the vacuum port opened, vacuum is directed to both sides of the diaphragm and the return spring holds the diaphragm away from the master cylinder in the released position.

b. Applied Position (D, Fig. 34-24). As the brake pedal is depressed, the valve operating rod moves to the left, which causes the valve plunger to move left also. The valve return spring then is compressed as the plunger moves and the poppet valve then comes in contact with the vacuum port seat. As this happens, the vacuum port to the right side of the diaphragm closes. Continued application of the brake pedal causes the atmospheric port to open by the valve rod forcing the valve plunger away from the poppet. As this happens, atmospheric air pressure rushes into the control vacuum chamber and applies pressure to the hydraulic push rod.

c. Holding Position (E, Fig. 34-24). As the driver stops depressing the brake pedal, the plunger also will stop moving. The reaction of the brake fluid transmitted through the reaction disk now will shift the valve plunger slightly to the right, which shuts off the atmospheric port. As this position is held, both sides of the diaphragm contain unchanging amounts of pressure, which

643


TO VACUUM
AIR
VACUUM
VACUUM
ATMOSPHERE
TO VACUUM
VACUUM
AIR

A. ATMOSPHERIC (AIR) SUSPENDED

B. VACUUM SUSPENDED

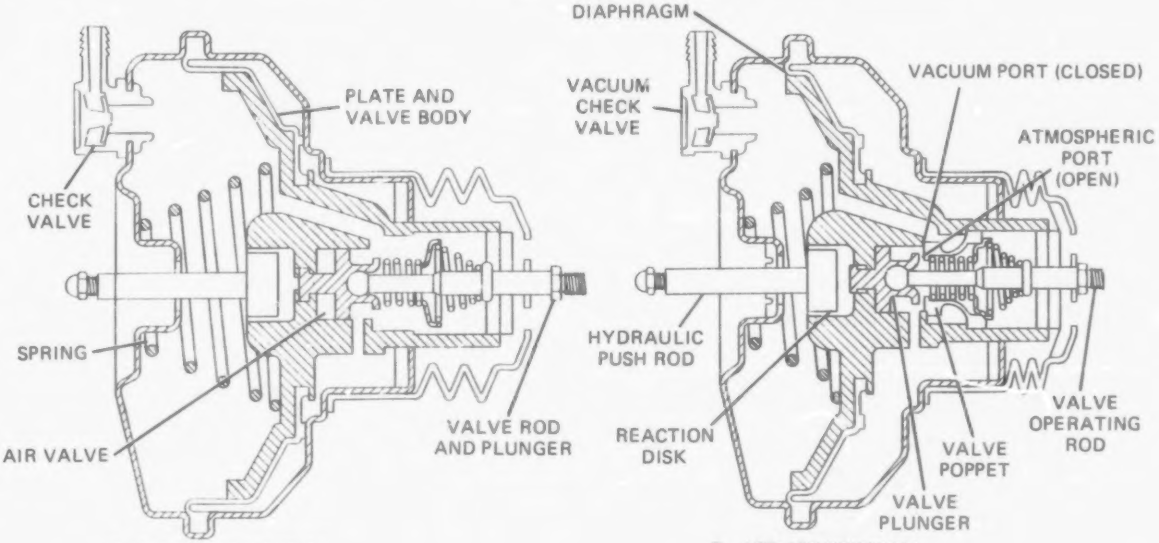
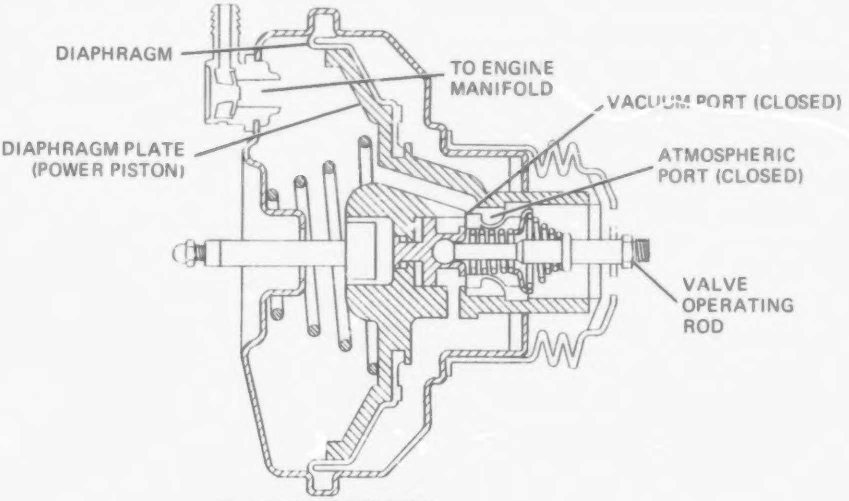


PLATE AND VALVE BODY
CHECK VALVE
SPRING
AIR VALVE
VALVE ROD AND PLUNGER
DIAPHRAGM
VACUUM CHECK VALVE
VACUUM PORT (CLOSED)
ATMOSPHERIC PORT (OPEN)
HYDRAULIC PUSH ROD
REACTION DISK
VALVE OPERATING ROD
VALVE POPPET
VALVE PLUNGER

C. RELEASED POSITION

D. APPLIED POSITION


DIAPHRAGM
TO ENGINE MANIFOLD
VACUUM PORT (CLOSED)
DIAPHRAGM PLATE (POWER PISTON)
ATMOSPHERIC PORT (CLOSED)
VALVE OPERATING ROD

E. HOLDING POSITION

Figure 34-24. Power Booster and Operation.

TA233876

644

exerts a steady amount of pressure on the master cylinder piston.

34-33. Tandem Booster. The tandem booster (fig. 34-25) makes use of dual diaphragm plates to increase the apply pressure to the master cylinder piston assembly. This is used for heavy-duty application on some larger vehicles.

34-34. Piston Booster. The piston-type booster (fig. 34-26) uses a sliding piston assembly fitted to the outer shell of the booster. The piston is provided with seals to assist in airtight operation.

34-35. Bellows Booster. The bellows-type booster (fig. 34-27) works by an expanding and contracting bellows. The booster usually is mounted above the brake pedal pivot point and acts against the brake pedal itself, rather than the master cylinder.

34-36. Brake-Pedal Booster. The brake-pedal booster (fig. 34-28) is configured the same way

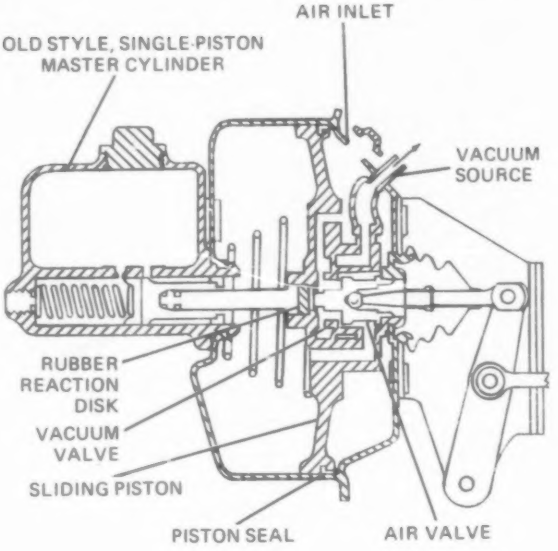

AIR INLET
OLD STYLE, SINGLE-PISTON MASTER CYLINDER
VACUUM SOURCE
RUBBER REACTION DISK
VACUUM VALVE
SLIDING PISTON
PISTON SEAL
AIR VALVE

Figure 34-26. Piston-Type Booster.

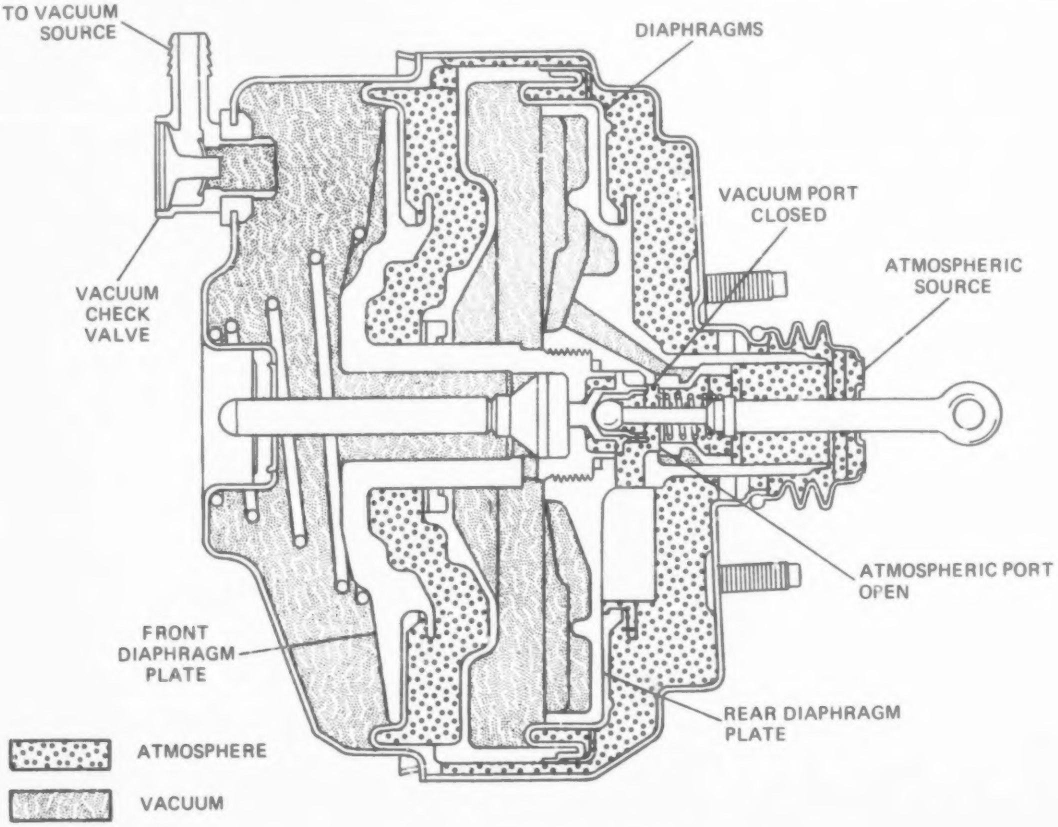

TO VACUUM SOURCE
DIAPHRAGMS
VACUUM PORT CLOSED
ATMOSPHERIC SOURCE
VACUUM CHECK VALVE
ATMOSPHERIC PORT OPEN
FRONT DIAPHRAGM PLATE
REAR DIAPHRAGM PLATE
ATMOSPHERE
VACUUM

Figure 34-25. Tandem-Type Booster.

TA233877

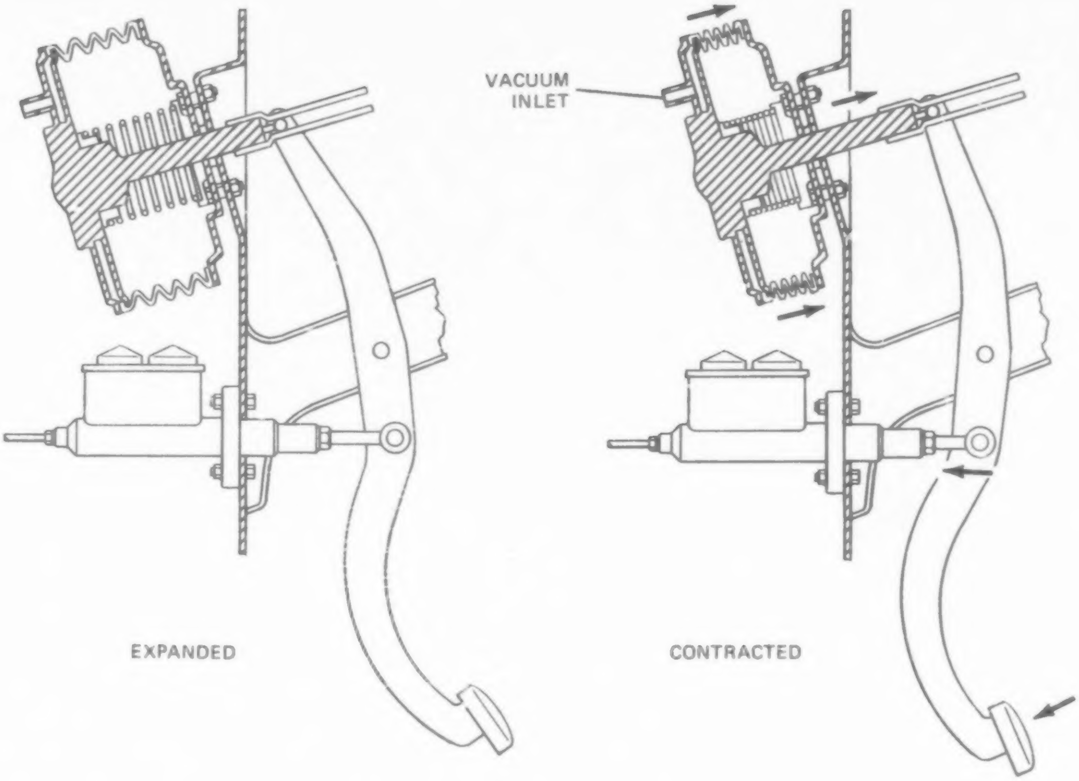


Figure 34-27. Bellows-Type Booster.

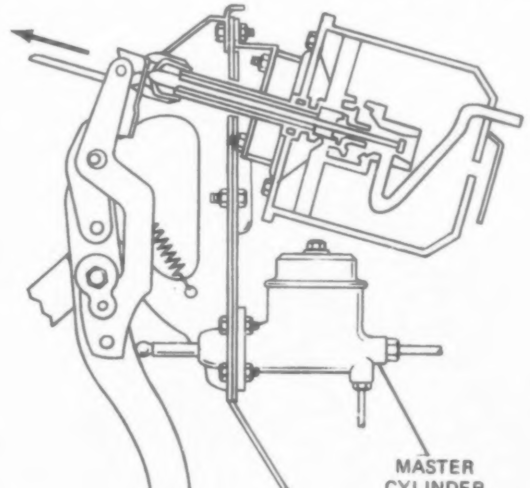


Figure 34-28. Brake-Pedal Booster.

as the bellows type. The power assist unit, however, is of the sliding piston or diaphragm type.

34-37. Hydraulic-Power Booster. The hydraulic-power booster, also called a hydroboost (fig. 34-29), is operated by hydraulic pressure developed by the power steering pump. Should the power steering pump become inoperative, an auxiliary electric pump then is used for backup and safety reasons. The hydraulic booster is attached directly to the master cylinder and is actuated by the brake pedal. The hydroboost system has an accumulator built into the system. The accumulator, which is spring loaded and can also contain pressurized gas, is filled with fluid, and pressurized whenever the brakes are applied. Should the power steering system fail because of a lack of fluid or a broken belt, the accumulator will retain enough fluid and pressure for about three brake applications.

TA233878

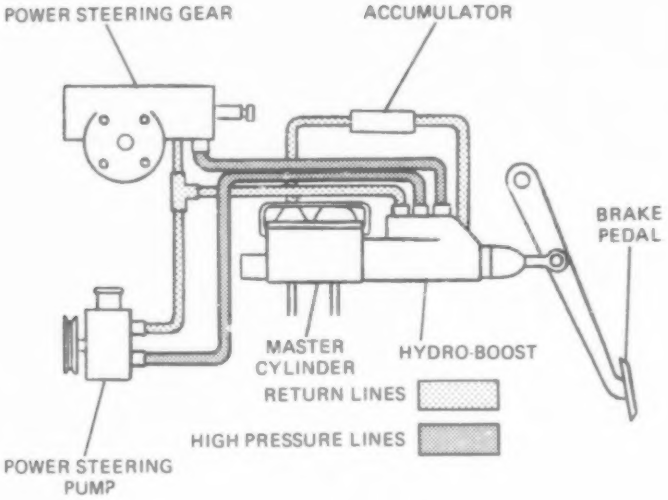


Figure 34-29. Hydraulic-Power Booster.

Section VIII. AIRBRAKE SYSTEM

34-38. Pneumatic Principle. Unlike liquids, gases are compressed easily. If a gas, such as air, is continued and a force applied to it, it is compressed and has less volume. Such a force can be exerted by placing a weight on a piston that fits into a container. The air that originally filled the entire container is pressed into only a portion of the container, due to the force of the weight upon it (fig. 34-30). The pressure of the compressed air, resulting from the force exerted upon it by the weight, will be distributed equally in all directions just as it is in a liquid. Compressed air under pressure may be stored conveniently and made available for the power application of brakes.

a. *Essential Action.* An air pump or compressor driven by the engine is used to compress air and force it into a reservoir, where it is forced under pressure and made available for operating the brakes. Air under pressure in the reservoir is released to the brake lines by an air valve operated by the brake pedal. This released air goes to brake chambers (located close to the wheel brakes), which contain a flexible diaphragm. Against this diaphragm is a plate that is connected directly to the mechanism on the wheel brakes by linkage. The force of the compressed air admitted to the chamber causes the diaphragm to move the plate and operate the brakeshoes through the linkage. Considerable force is available for braking, because operating air pressure can be as high as 100 psi. All brakes on a vehicle, and on a trailer when one is used, are operated together by means of special regulating valves.

b. *Fundamental Units.* A diagram of a typical airbrake system used on a motor vehicle is shown in figure 34-31. The fundamental units and their functions are described in paragraph 34-39.

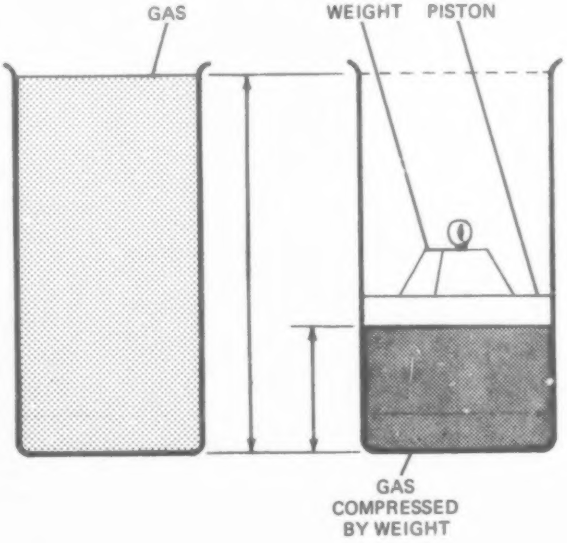


Figure 34-30. Pneumatic Principle.

TA233879

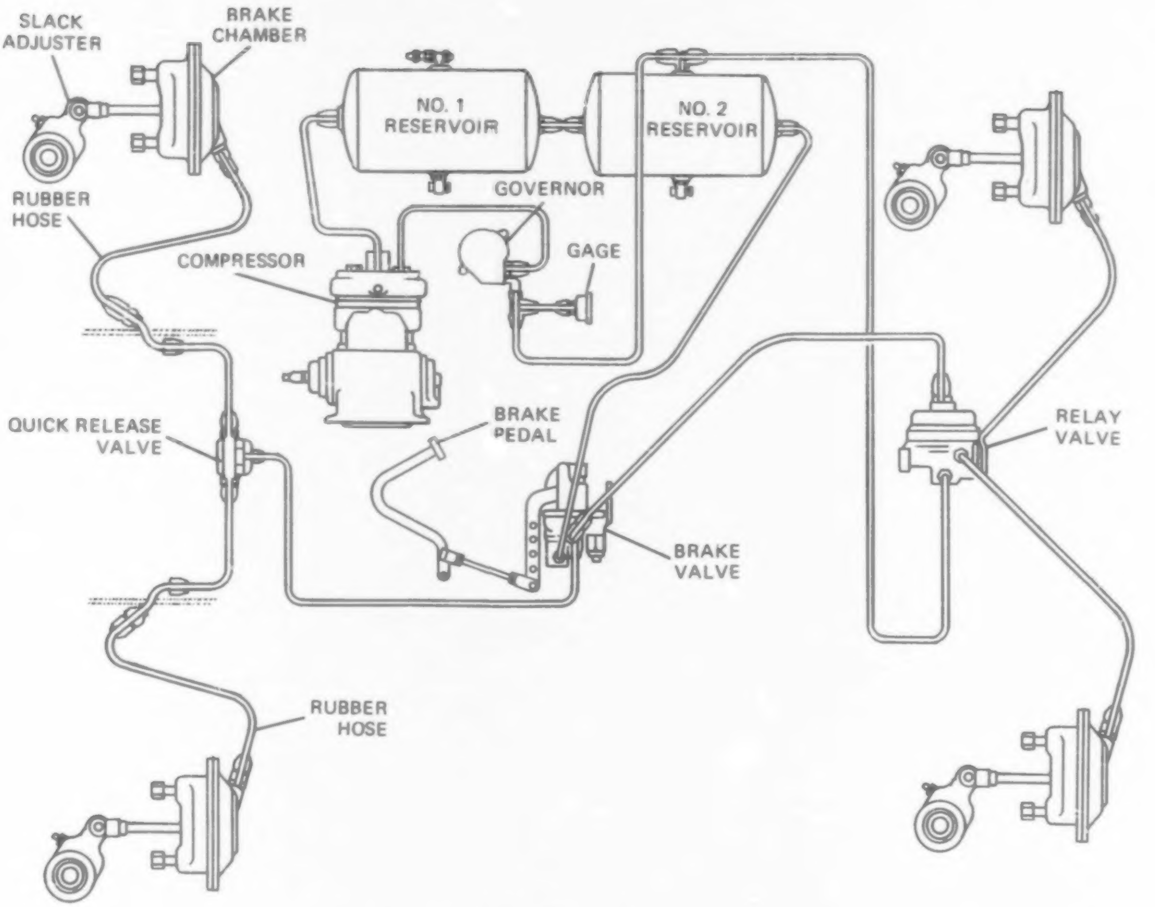


Figure 34-31. Typical Airbrake System.

34-39. System Components.

a. Air Compressor. Air compressors usually are single-acting reciprocating units, either self-lubricated or lubricated from the vehicle engine lubricating system. Both water-cooled and air-cooled cylinder heads are used. Compressors having a displacement of approximately 7 cfm have two cylinders (fig. 34-32), while those with a displacement of 12 cfm have three cylinders (fig. 34-33).

The air compressors operate continuously while the engine is running, but the actual compression of air is controlled by the governor.

With a partial vacuum created on the piston downstroke, intake ports are uncovered near the bottom of the stroke. Intake ports are covered as the piston starts its upstroke. Air in the cylinder is compressed. The pressure developed lifts the discharge valve and the compressed air is discharged to the reservoirs (fig. 34-32). The discharge valve closes as soon as pressure is relieved when the piston starts its downstroke.

b. Unloader. When the reservoir air pressure reaches the maximum setting of the governor, air under pressure is allowed by the governor to pass into a cavity below an unloading diaphragm in the cylinder head. This air pressure lifts one end of the unloading lever, which pivots on its pin and forces the unloading valves off their seats. With the unloading valves off their seats, the unloading cavity forms a passage between the cylinders above the pistons. Air then passes back and forth through the cavity between the cylinders and compression is stopped. A drop in air pressure below the minimum setting of the governor causes

TA233880

648

BEST COPY AVAILABLE

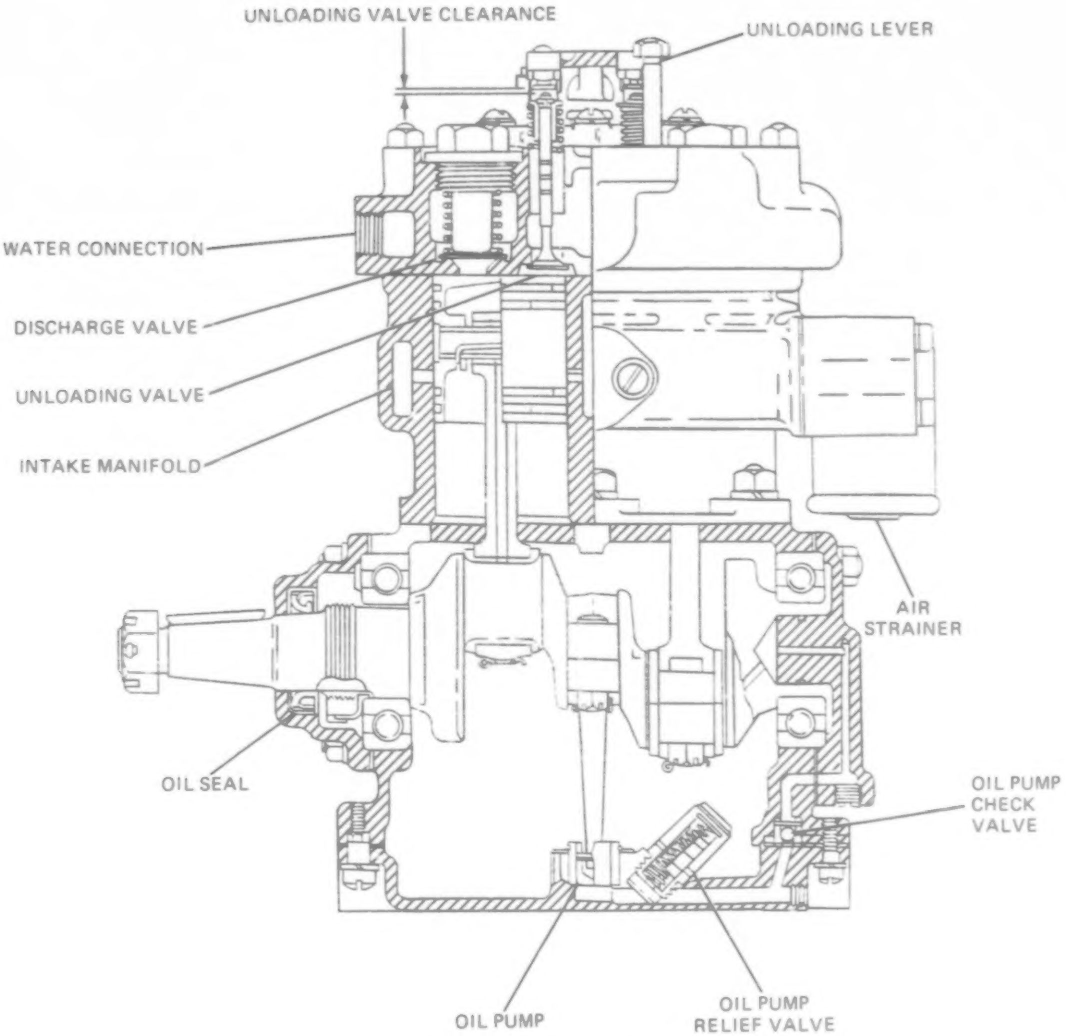

UNLOADING VALVE CLEARANCE
UNLOADING LEVER
WATER CONNECTION
DISCHARGE VALVE
UNLOADING VALVE
INTAKE MANIFOLD
AIR STRAINER
OIL SEAL
OIL PUMP CHECK VALVE
OIL PUMP
OIL PUMP RELIEF VALVE

Figure 34-32. Typical Air Compressor, Two-Cylinder.

it to release the air pressure from beneath the unloading diaphragm, allowing the unloading valves to return to their seats. Compression then is resumed (fig. 34-32).

c. Governor. The governor maintains the air pressure in the reservoir between the desired maximum and minimum values, by controlling the compressor unloading mechanism. The Bourdon gage principle of a curved metal tube that tends to straighten under internal pressure is utilized. Air under pressure from the reservoir always is present below the lower valve and in the tube. As air pressure increases, the load of the tube (fig. 34-34) on the lower valve is relieved, because the tube tends to straighten. When reservoir air pressure reaches the cutout setting of the governor, the spring tube load on the valves has been reduced sufficiently to permit the air pressure to raise the valves. The upper valve closes the exhaust port and the lower valve opens the connection for the air under pressure to the compressor unloading mechanism. If air pressure drops to the governor cut-in setting, the pressure of the spring tube on the valves increases and forces the valves down, opening the upper valve and seating the lower valve. Air under pressure from the unloading mechanism is allowed to escape through the exhaust port while the air under pressure from the reservoir is sealed off by the lower valve.

TA233881

649

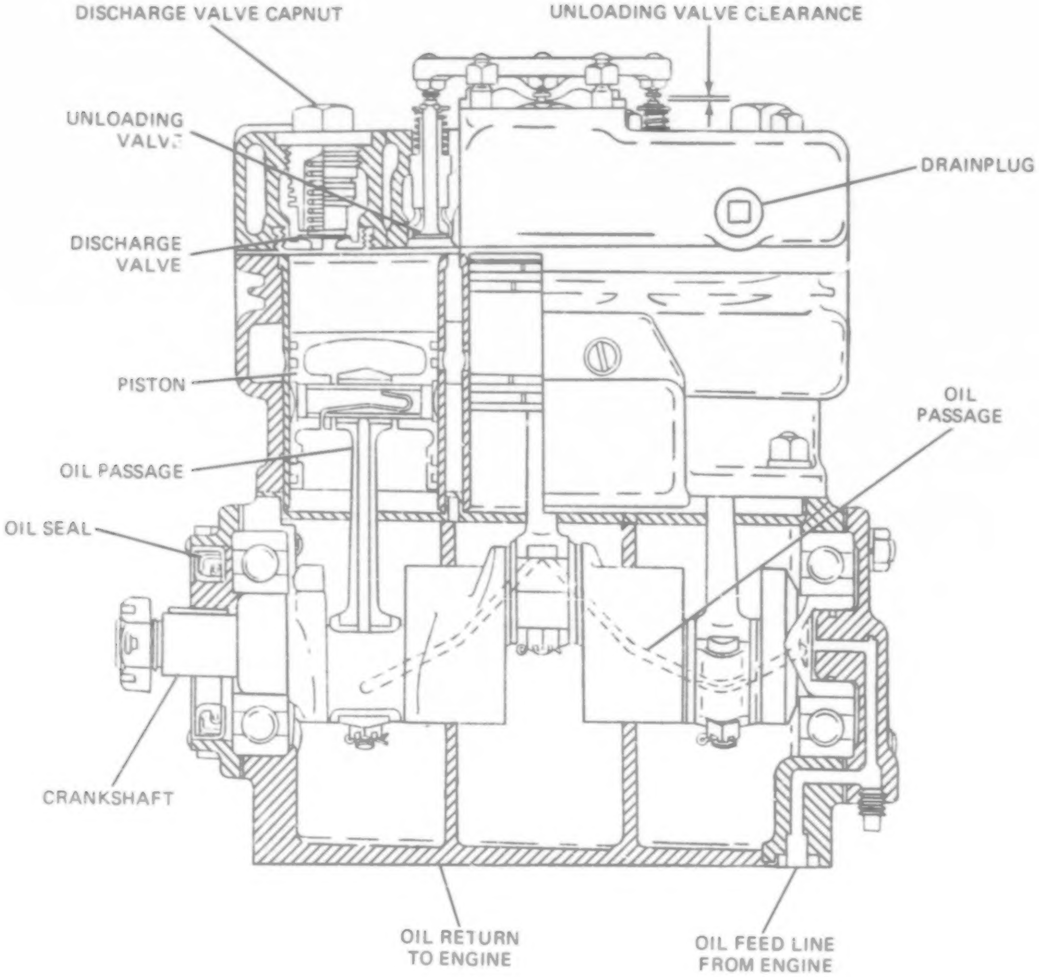

DISCHARGE VALVE CAPNUT
UNLOADING VALVE CLEARANCE
UNLOADING VALVE
DRAINPLUG
DISCHARGE VALVE
PISTON
OIL PASSAGE
OIL PASSAGE
OIL SEAL
CRANKSHAFT
OIL RETURN TO ENGINE
OIL FEED LINE FROM ENGINE

Figure 34-33. Typical Air Compressor, Three-Cylinder.

d. Airbrake valve. The airbrake valve lever is connected to the brake pedal. Movement of the lever controls the operation of the inlet and exhaust valves (fig. 34-35) that control the air under pressure delivered to or released from the brake chambers. As the brake pedal is depressed, the brake valve lever moves toward its applied position. The plunger and regulating spring are forced down, applying mechanical force on the diaphragm. The exhaust valve spring is weaker than the intake valve spring, so the exhaust valve is forced downward onto its seat before the intake valve is opened. When the intake valve opens, air from the reservoir is allowed to flow through the brake valve to the brake chambers to apply the brakes. When the air pressure below the diaphragm overcomes the mechanical force exerted on top of the diaphragm, the diaphragm lifts sufficiently to close the intake valve and maintain the system in the holding position. Further depression of the pedal puts additional mechanical force on the diaphragm, thereby allowing further brake application. If the driver releases the brake pedal, reducing the mechanical force on the diaphragm, the inlet valve remains closed, while the exhaust valve opens to allow the air under pressure to be exhausted from the brake chambers to release the brakes.

e. Brake Chamber. The brake chamber (fig. 34-36) converts the energy of the compressed air into mechanical force to operate the brakes. Air

TA233882

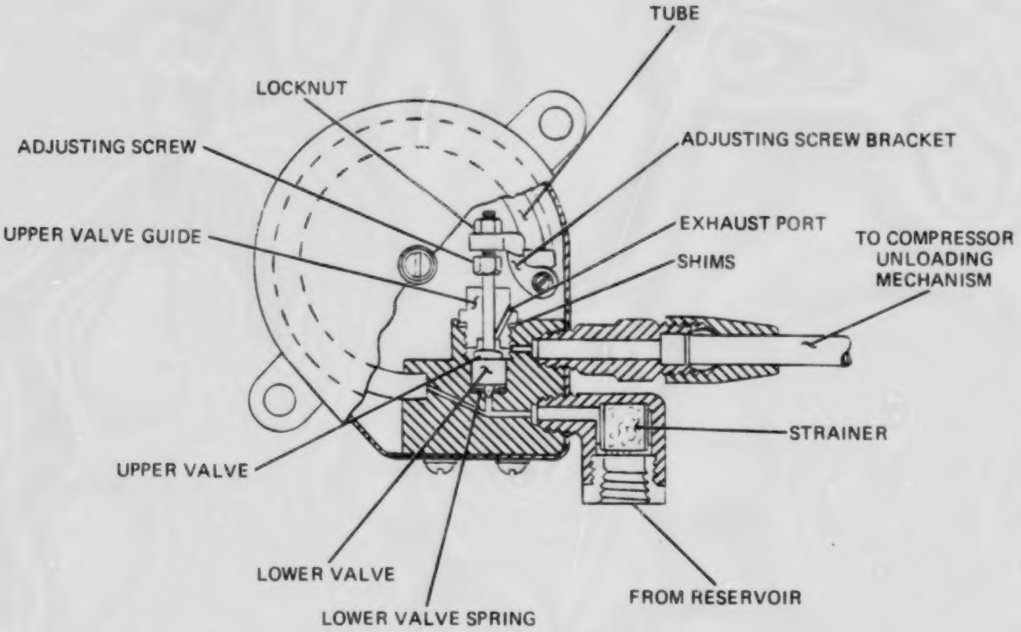

TUBE
LOCKNUT
ADJUSTING SCREW
ADJUSTING SCREW BRACKET
EXHAUST PORT
UPPER VALVE GUIDE
SHIMS
TO COMPRESSOR UNLOADING MECHANISM
STRAINER
UPPER VALVE
LOWER VALVE
FROM RESERVOIR
LOWER VALVE SPRING

Figure 34-34. Governor.

under pressure enters the brake chamber behind the diaphragm and forces the push rod out against the return spring force. Because the yoke on the end of the push rod is connected to the slack adjuster, this movement rotates the slack adjuster, brake camshaft, and cam to apply the brakes.

f. *Quick Release Valve.* The quick release

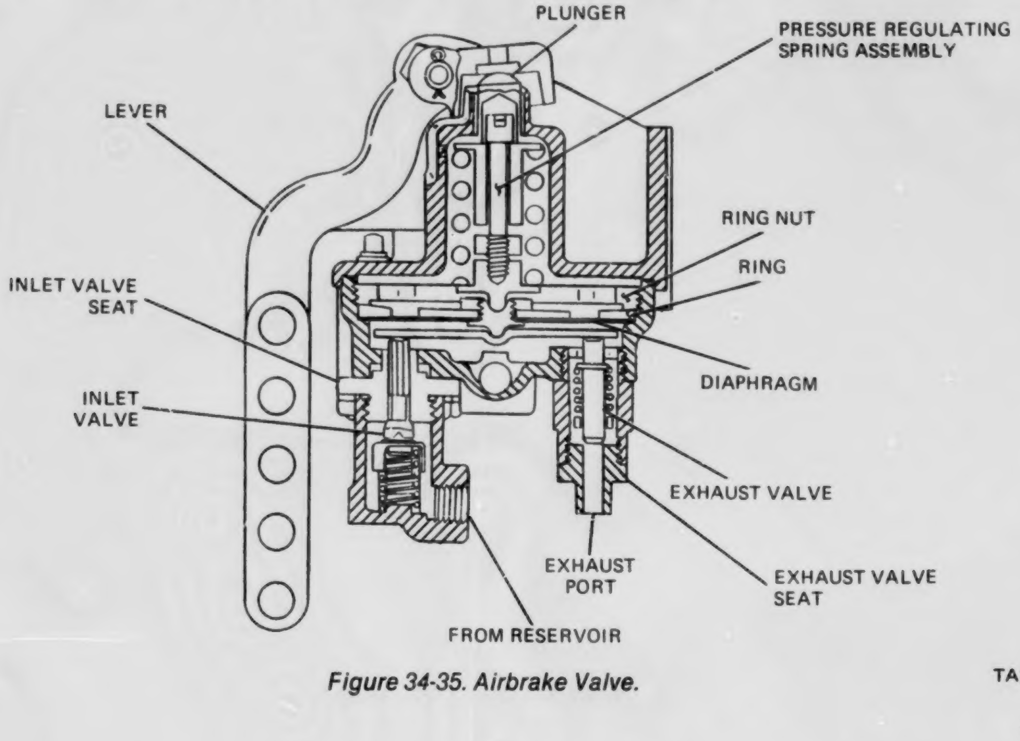

PLUNGER
PRESSURE REGULATING SPRING ASSEMBLY
LEVER
RING NUT
RING
INLET VALVE SEAT
DIAPHRAGM
INLET VALVE
EXHAUST VALVE
EXHAUST PORT
EXHAUST VALVE SEAT
FROM RESERVOIR

Figure 34-35. Airbrake Valve.

TA233883

651

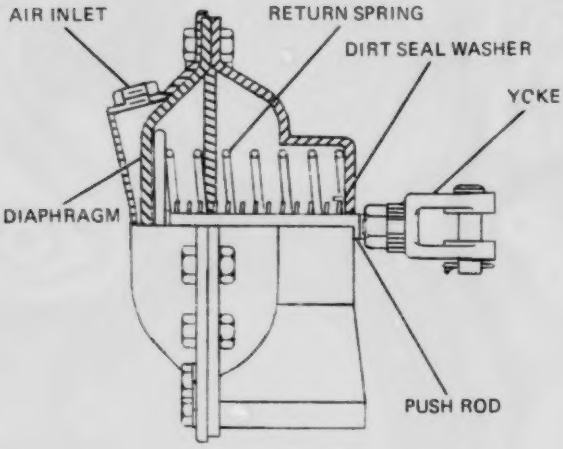


Figure 34-36. Brake Chamber.

valve is provided to reduce the time required to release the brakes by hastening the exhaust of air under pressure from the brake chambers. The valve contains a spring-loaded diaphragm arranged so as to permit airflow through the valve in only one direction. In the brake application position, air under pressure from the brake valve enters the inlet port (fig. 34-37). The diaphragm is forced downward and closes the exhaust port. The air under pressure then deflects the outer edges of the diaphragm downward and enters the brake chambers to apply the brakes. As soon as the air pressure in the chambers and below the diaphragm equals the air pressure above the diaphragm, the diaphragm spring forces the outer edge of the diaphragm up against the valve body, closing off the brake chambers from the inlet port. In this holding position, the diaphragm continues to keep the exhaust valve closed. If the pressure above the diaphragm is reduced or completely released by the driver releasing the brake pedal partially or completely, the air pressure below the diaphragm causes the diaphragm to be raised to open the exhaust port and release the brake chamber air pressure.

g. Relay Valve. The relay valve (fig. 34-38) is controlled by the brake valve, and speeds up application and release of the rear wheel brakes for long wheelbase vehicles. It reacts quickly to slight changes in air pressure from the brake valve. When the brake pedal is operated, air under pressure from the brake valve is delivered through the port to the cavity above the diaphragm (fig. 34-38). Because this cavity is comparatively small, it is subject to quick changes in air pressure, causing the valve to react quickly. Operation of the valve is similar to that of the quick release valve. Air pressure from the brake valve forces the diaphragm down to close the exhaust port beneath the diaphragm outer edge. Further air pressure depresses the center of the diaphragm, opening the supply valve, and compressed air flows into the cavity below the diaphragm and into the brake chambers. As soon as the air pressure above the diaphragm is equalized by the brake chamber air pressure, the diaphragm is raised to the holding position, closing the supply valve and keeping the exhaust port closed. When the air pressure above the diaphragm is reduced by the operator releasing the brake pedal, the brake chamber air pressure lifts the diaphragm, opening the exhaust port and exhausting the compressed air pressure from the brake chamber.

h. Slack Adjuster. Slack adjusters (fig. 34-39) function as adjustable levers and provide a means of adjusting the brakes to compensate for wear of linings. During brake operation, the entire slack adjuster rotates with the brake camshaft, which is connected to the slack adjuster through the splined central hole. For brake adjustment, the worm moves the gear, changing the position of the lever arm with respect to the camshaft.

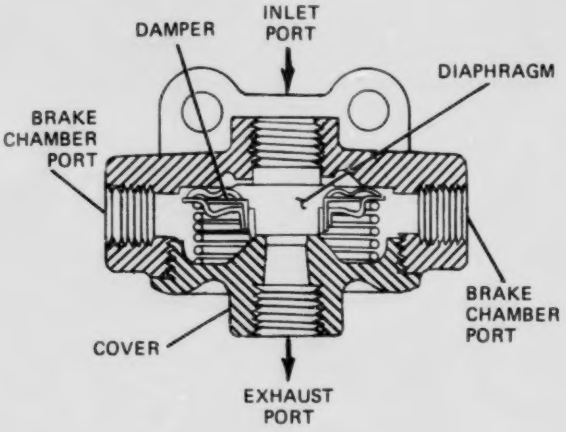
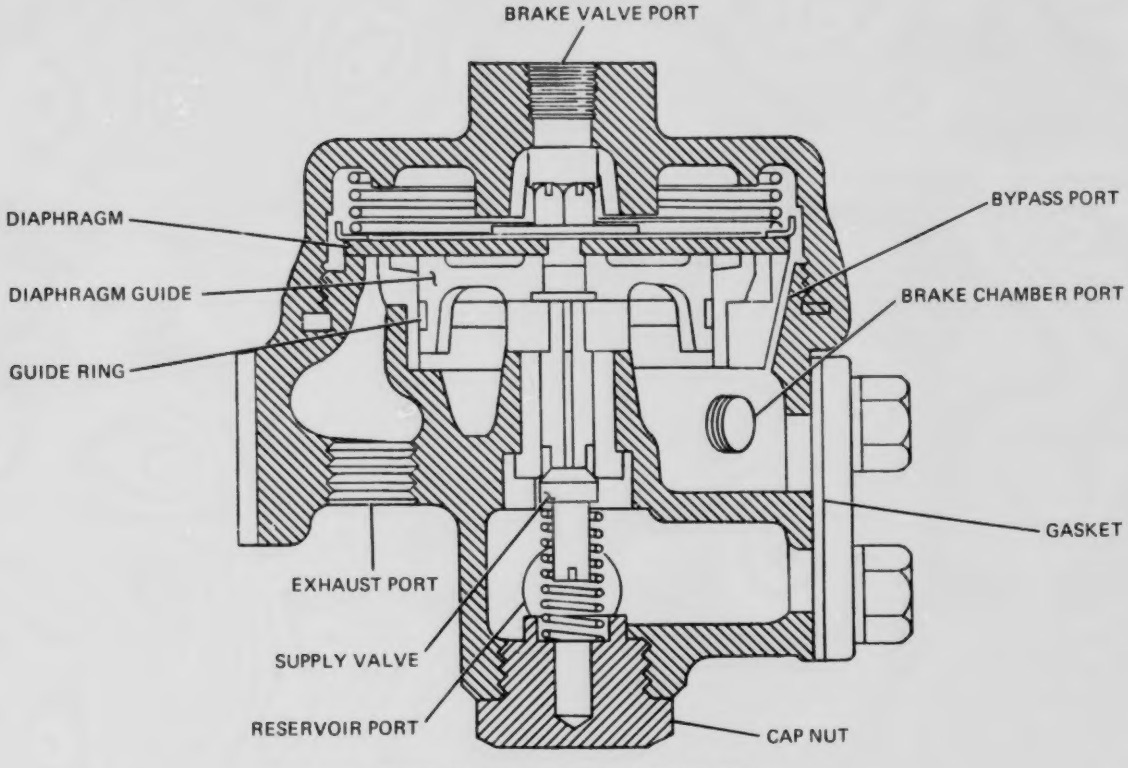


Figure 34-37. Quick Release Valve.

TA233884

G52


BRAKE VALVE PORT
DIAPHRAGM
DIAPHRAGM GUIDE
GUIDE RING
BYPASS PORT
BRAKE CHAMBER PORT
GASKET
EXHAUST PORT
SUPPLY VALVE
RESERVOIR PORT
CAP NUT

RELAY VALVE – CROSSSECTIONAL VIEW

Figure 34-38. Relay Valve.

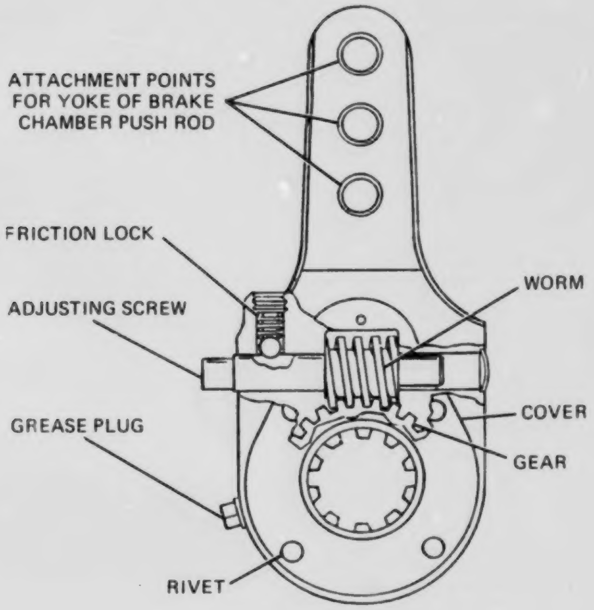

ATTACHMENT POINTS FOR YOKE OF BRAKE CHAMBER PUSH ROD
FRICTION LOCK
WORM
ADJUSTING SCREW
COVER
GREASE PLUG
GEAR
RIVET

Figure 34-39. Slack Adjuster – Partial Cutaway View.

TA233885

653

BEST COPY AVAILABLE

Section IX. AIR-OVER-HYDRAULIC BRAKE SYSTEM

34-40. Construction. The air-over-hydraulic brake system is shown in figure 34-40. Air pressure is supplied by a compressor and stored in reservoirs, as with the airbrake system. The master cylinder is similar to the master cylinders used in hydraulic brakes. Also, the wheel brake cylinders and wheel brake construction are very similar to that used in hydraulic brakes. The essential difference between the straight hydraulic brake system and the air-over-hydraulic brake system lies in the air-hydraulic cylinder. This cylinder consists of three essentials: a large-diameter air piston; a small-diameter hydraulic piston in tandem with it, both on the same rod; and a set of valves controlled by hydraulic pressure from the master cylinder for admitting air into the air-cylinder section of the air-hydraulic cylinder.

34-41. Operation. The air-hydraulic cylinder (fig. 34-40) consists of an air cylinder and a hydraulic cylinder in tandem, each fitted with a piston with a common piston rod between. The air piston is of greater diameter than the hydraulic piston. This difference in areas of the two pistons gives a resultant hydraulic pressure much greater than the air pressure admitted to the air cylinder. Automatic valves, actuated by fluid pressure from master cylinder, control the air admitted to the air cylinder. Thus, the fluid pressure in brake lines is always in a direct ratio to foot pressure on brake pedal. An air line from an air-hydraulic cylinder leads to a trailer coupling at the rear of vehicle.

Valve action varies with the amount of brake pedal pressure, as mentioned in paragraph 34-39d. When heavy brake pedal pressure is applied by the

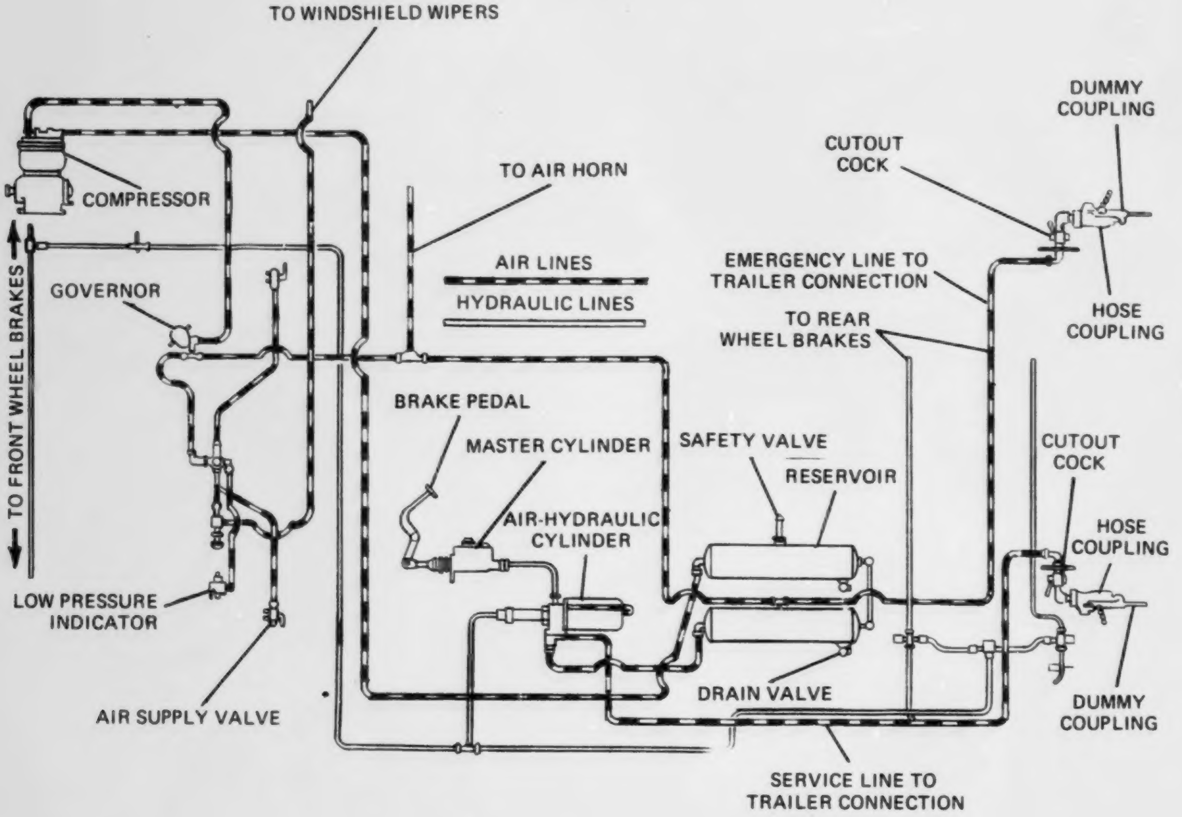

TO WINDSHIELD WIPERS
COMPRESSOR
TO FRONT WHEEL BRAKES
GOVERNOR
LOW PRESSURE INDICATOR
AIR SUPPLY VALVE
TO AIR HORN
AIR LINES
HYDRAULIC LINES
BRAKE PEDAL
MASTER CYLINDER
AIR-HYDRAULIC CYLINDER
SAFETY VALVE
RESERVOIR
DRAIN VALVE
SERVICE LINE TO TRAILER CONNECTION
CUTOUT COCK
DUMMY COUPLING
EMERGENCY LINE TO TRAILER CONNECTION
TO REAR WHEEL BRAKES
HOSE COUPLING
CUTOUT COCK
HOSE COUPLING
DUMMY COUPLING

Figure 34-40. Air-Over-Hydraulic Brake System. TA233886

652

BEST COPY AVAILABLE

driver for hard braking, the hydraulic pressure in the master cylinder (which operates the valves) causes greater valve movement, and therefore, the valves admit more air pressure into the air-hydraulic cylinder. This higher air pressure causes a stronger braking action. With only a light brake pedal pressure, the valves admit less air pressure into the air-hydraulic cylinder and the braking action is lighter.

Section X. VACUUM-OVER-HYDRAULIC BRAKE SYSTEM

34-42. Construction. Hydrovac is the trade name for a one-unit, vacuum-power braking system. It combines a hydraulically actuated control valve, a tandem piston vacuum- power cylinder, and a hydraulic slave cylinder into one assembly. It is connected hydraulically to both the master cylinder and the wheel brakes, eliminating the need for mechanical connections with the brake pedal and linkage.

The vacuum-power cylinder is divided into four compartments by the front and rear pistons and the center plate. The vacuum source is connected directly to the compartment between the center plate and rear piston. The vacuum is connected from this compartment, by means of the vacuum line, to the relay or control valve. From the control valve, the vacuum is connected to the front compartment by a passage in the valve body.

34-43. Operation. In the released position (fig. 34-41), with the control valve diaphragm plate and the vacuum valve seat held down by the valve spring to keep the vacuum valve open and the atmospheric valve closed, the vacuum is connected through the vacuum valve and atmospheric control line to the compartment between the center plate and front piston and, through the ports in the hollow piston rod, to the rear compartment. Vacuum , therefore, is present in all four compartments in the released position and both pistons remain inoperative. The piston return spring holds the pistons in the OFF position. The push rod, in the released position, maintains the bypass (check) valve off its seat, permitting a direct hydraulic connection from the master cylinder, through the hydraulic slave cylinder, to the wheel cylinders. With this construction, foot pedal pressure can be applied to the wheel cylinders for braking action, should vacuum or Hydrovac failure make the power cylinder inoperative. The relay valve diaphragm has vacuum on both sides and is held in the OFF position by the valve spring. When the vacuum in the Hydrovac is the same as, or greater than, the source vacuum, the poppet valve in the vacuum check valves rests on its seat and, in the event of engine failure or rapid acceleration, traps the vacuum in the Hydrovac system in readiness for brake application. As the foot pedal is depressed, fluid is forced from the master cylinder through the open bypass (check) valve to the slave cylinder and on to the wheel cylinders. The fluid also is forced through the drilled bypass passage to the relay valve hydraulic piston, which is forced outward against the pressure of the valve spring, gradually forcing the diaphragm plate and vacuum valve seat toward the applied position. The movement of the diaphragm first closes the vacuum valve against its seat, sealing off the vacuum from the atmospheric control line. After the vacuum valve is seated, further motion of the diaphragm causes the atmospheric valve to leave its seat, permitting air from the air cleaner to enter the atmospheric control line, then to the compartment between the center plate and front piston and, through the hollow piston rod, to the rear compartment (fig. 34-42). With the vacuum still present on the front sides of both pistons, and atmospheric pressure on the rear sides of both pistons, the pistons are caused to move toward the slave cylinder by the difference in pressure. Movement of the pistons and push rod toward the slave cylinder first closes the bypass (check) valve, and causes the slave-cylinder piston to move outward, forcing fluid under high pressure into the wheel cylinders to apply the brakes. The foot pedal pressure, acting through the master cylinder, also acts against the slave-cylinder piston, assisting the vacuum pistons and push rod. The pressure at the wheel cylinders (that is, the total braking effort) is the sum of the output of the vacuum pistons in the Hydrovac and of the foot pedal pressure at the master cylinder. Release of foot pedal pressure allows the valve spring in the relay or control valve to return the atmospheric and vacuum valves to the released position by removing the fluid pressure from below the relay valve hydraulic piston. The atmosphere is exhausted from the rear sides of both pistons,

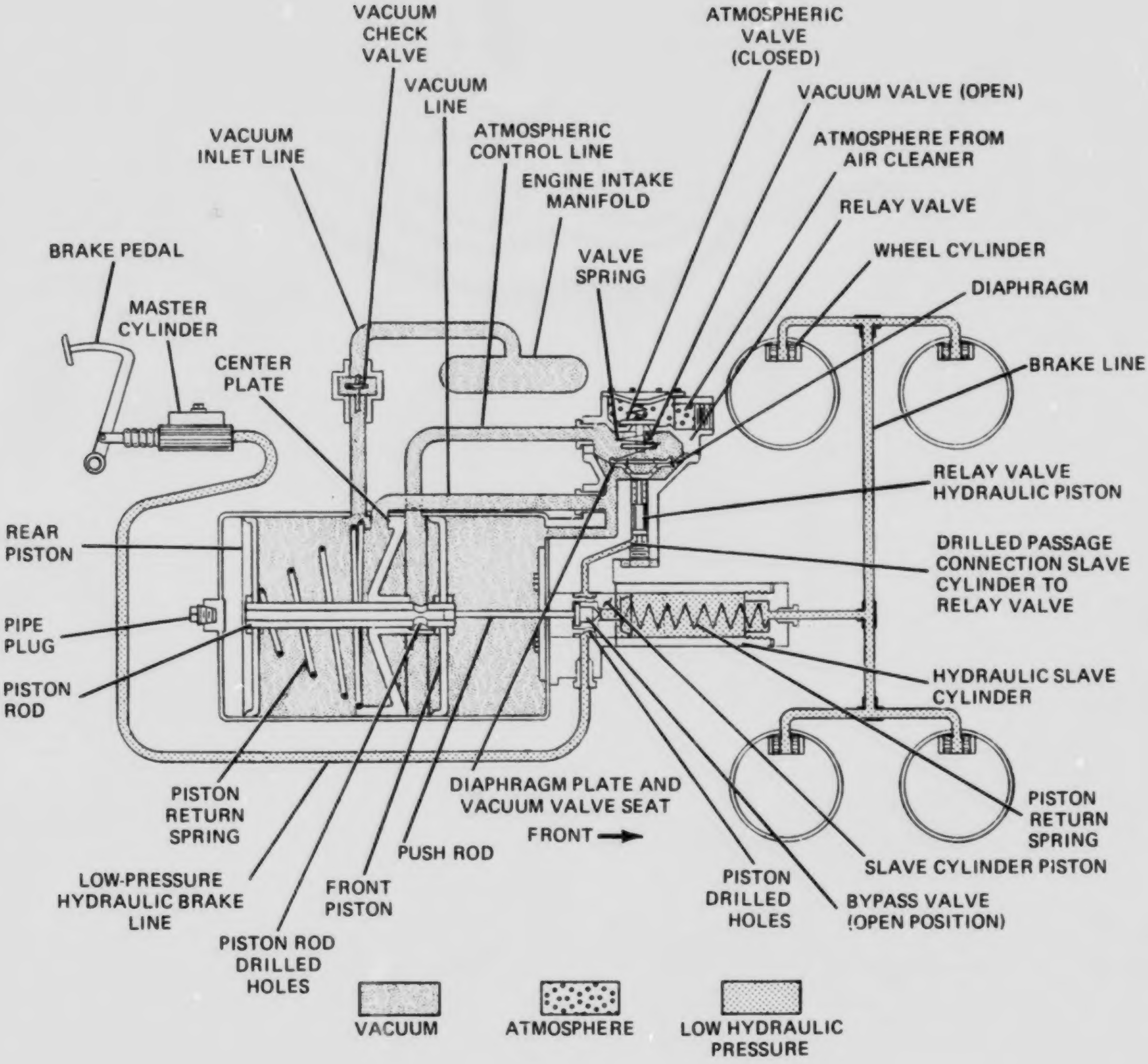
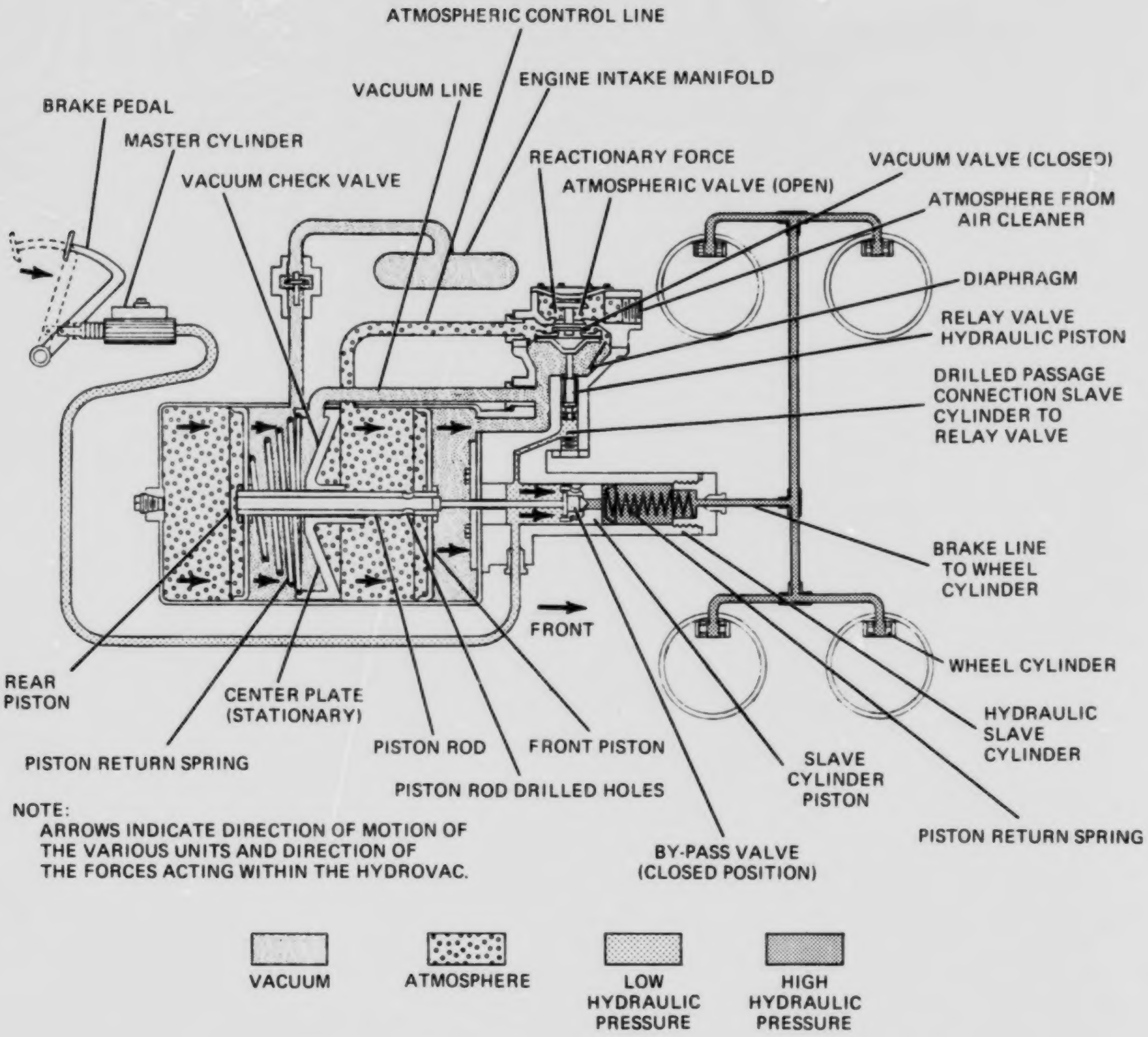

VACUUM CHECK VALVE
VACUUM LINE
VACUUM INLET LINE
ATMOSPHERIC CONTROL LINE
ENGINE INTAKE MANIFOLD
ATMOSPHERIC VALVE (CLOSED)
VACUUM VALVE (OPEN)
ATMOSPHERE FROM AIR CLEANER
RELAY VALVE
WHEEL CYLINDER
DIAPHRAGM
BRAKE PEDAL
MASTER CYLINDER
CENTER PLATE
VALVE SPRING
BRAKE LINE
RELAY VALVE HYDRAULIC PISTON
DRILLED PASSAGE CONNECTION SLAVE CYLINDER TO RELAY VALVE
REAR PISTON
PIPE PLUG
PISTON ROD
HYDRAULIC SLAVE CYLINDER
PISTON RETURN SPRING
DIAPHRAGM PLATE AND VACUUM VALVE SEAT
FRONT →
PUSH ROD
PISTON RETURN SPRING
SLAVE CYLINDER PISTON
LOW-PRESSURE HYDRAULIC BRAKE LINE
FRONT PISTON
PISTON DRILLED HOLES
BYPASS VALVE (OPEN POSITION)
PISTON ROD DRILLED HOLES
VACUUM
ATMOSPHERE
LOW HYDRAULIC PRESSURE

Figure 34-41. Vacuum-Over-Hydraulic Brake System – Released.

making them inoperative and allowing the piston return spring to move the pistons to the released position. When the foot pedal movement stops at some intermediate point between the released and fully applied position, the pistons will move toward the lap position so that the fluid pressure under the relay-valve hydraulic piston will be reduced the necessary amount to allow the diaphragm to drop and close both the atmospheric and vacuum valves in the control valve. Thereafter, the slightest foot pedal movement, either toward the released or the applied position, will result in the opening of either the vacuum or the atmospheric valve, and will release partially or apply further the brakes.

TA233887


ATMOSPHERIC CONTROL LINE
VACUUM LINE
ENGINE INTAKE MANIFOLD
BRAKE PEDAL
MASTER CYLINDER
VACUUM CHECK VALVE
REACTIONARY FORCE
ATMOSPHERIC VALVE (OPEN)
VACUUM VALVE (CLOSED)
ATMOSPHERE FROM AIR CLEANER
DIAPHRAGM
RELAY VALVE HYDRAULIC PISTON
DRILLED PASSAGE CONNECTION SLAVE CYLINDER TO RELAY VALVE
BRAKE LINE TO WHEEL CYLINDER
FRONT
WHEEL CYLINDER
HYDRAULIC SLAVE CYLINDER
REAR PISTON
CENTER PLATE (STATIONARY)
PISTON ROD
FRONT PISTON
PISTON RETURN SPRING
PISTON ROD DRILLED HOLES
SLAVE CYLINDER PISTON
PISTON RETURN SPRING
BY-PASS VALVE (CLOSED POSITION)
VACUUM
ATMOSPHERE
LOW HYDRAULIC PRESSURE
HIGH HYDRAULIC PRESSURE

NOTE:
ARROWS INDICATE DIRECTION OF MOTION OF THE VARIOUS UNITS AND DIRECTION OF THE FORCES ACTING WITHIN THE HYDROVAC.

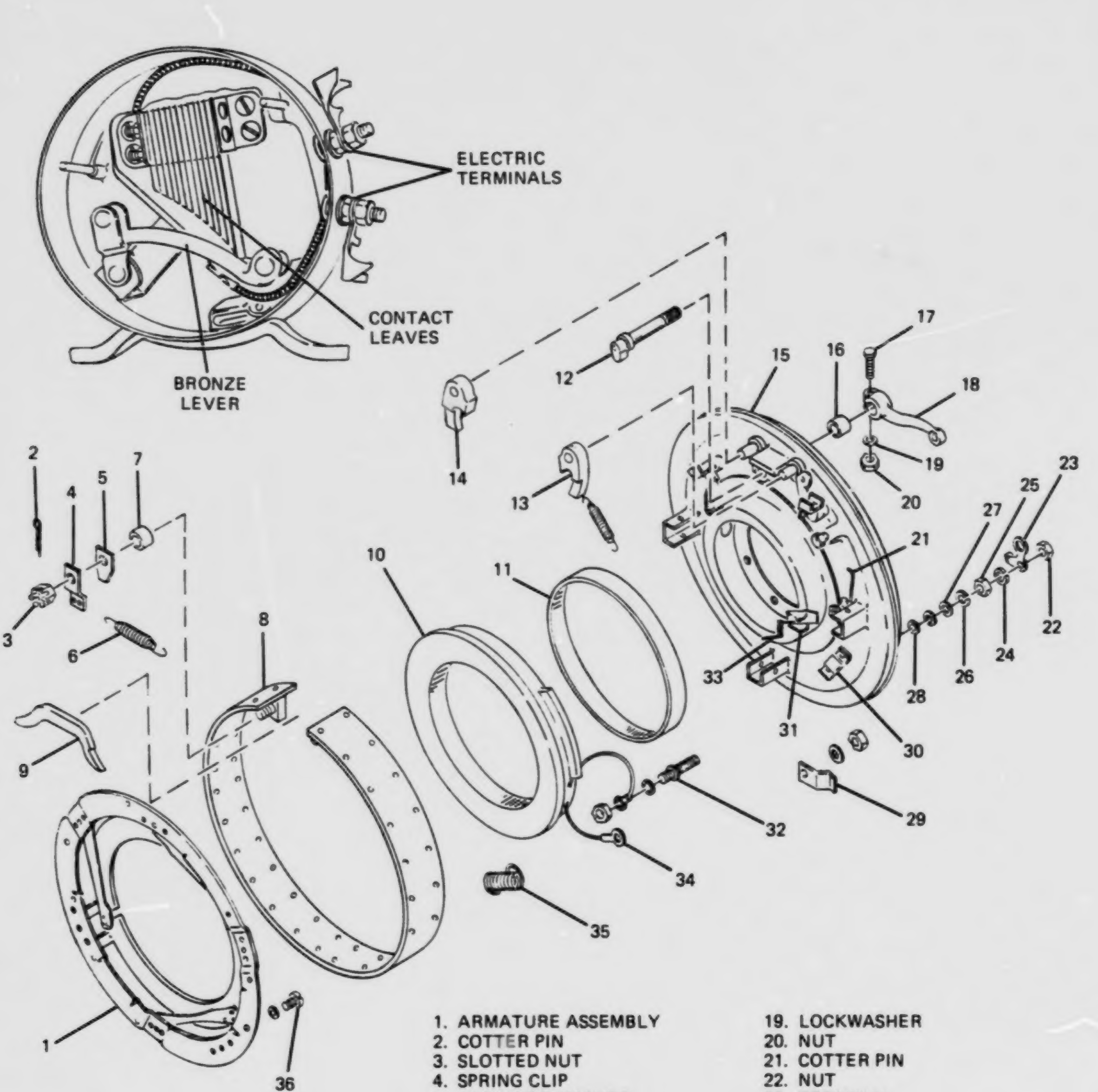
Figure 34-42. Vacuum-Over-Hydraulic Brake System – Applied.

Section XI. ELECTRIC BRAKE SYSTEM

34-44. Construction. The layout of the electric brake system, which operates from the storage battery or the electrical system, is quite simple. Wiring replaces the rods, cables, and tubings used in other types of brakes. The controller can be mounted at any convenient place in the driver's compartment. It usually is attached to the steering column. A bronze lever (fig. 34-43) within the controller, connected by linkage to the brake pedal, acts as a rheostat switch. The controller is provided with electrical terminals to connect it in the electric brake circuit. As the brake pedal is depressed, the bronze lever comes in successive contact with leaves of varying lengths and completes the electric circuit from the battery to an electromagnet in the brake.

Electric current is supplied to the electromagnet, the amount depending on the number of leaves contacted by the bronze lever. When the brake is fully depressed, all the leaves are in contact with the bronze lever and the maximum amount of current flows to the brake.

TA233888


ELECTRIC TERMINALS
CONTACT LEAVES
BRONZE LEVER
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36

1. ARMATURE ASSEMBLY
2. COTTER PIN
3. SLOTTED NUT
4. SPRING CLIP
5. RETAINER WASHER
6. BAND RETURN SPRING
7. ROLLER
8. BAND AND LINING ASSEMBLY
9. PARKING TRUST LEVER
10. MAGNET ASSEMBLY
11. MAGNET BUSHING
12. PARKING CAMSHAFT LEVER
13. LEFT-HAND CAM
14. RIGHT-HAND CAM
15. BACKING PLATE ASSEMBLY
16. BUSHING
17. BOLT
18. PARKING CAMSHAFT LEVER
19. LOCKWASHER
20. NUT
21. COTTER PIN
22. NUT
23. TERMINAL
24. LOCKWASHER
25. NUT
26. LOCKWASHER
27. BRASS WASHER
28. FIBER WASHER
29. WIRE CLAMP
30. INSIDE CONTACT INSULATOR
31. MAGNETIC HOLDDOWN BAR
32. STUD
33. MAGNETIC HOLDDOWN SPRING
34. MAGNETIC WIRE
35. MAGNETIC RETURN SPRING
36. SCREW

Figure 34-43. Electric Brake System.

TA233889

34-45. Operation. The armature assembly revolves with the brakedrum and is kept in constant contact with the electromagnet by means of flat springs. When the brake pedal is depressed, the current flows from the controller to the brake and through a coil of copper wire in the magnet, setting up a magnetic field and causing the magnet to attract the armature. The farther the foot pedal is depressed, the greater the amount of current is that reaches the magnet and the tighter the magnet clings to the armature. This attraction of the magnet to the armature causes the magnet, which can revolve within a limited arc, to start turning with the armature. As the magnet turns, it engages a cam lever, which in turn expands the brake band evenly against the brakedrum in the conventional way.

When the current is cut off by removing pressure from the brake pedal, the magnet in each brake is demagnetized and remains stationary. The brake return springs release the brake bands from contact with the brakedrums.

The principle of the electric brake permits use of a self-adjusting feature to compensate for lining wear. As the brake band wears, the electromagnet moves a little farther to drive the brake lining against the surface of the drum. An automatic stop on the brake band prevents the rivets from coming into contact with the drum after excessive wear, eliminating danger of scoring of the drum. If the vehicle is standing still and the current is turned on, there is no action of the brakes. If the wheel revolves in the slightest degree, however, the brake is operated.

PART SIX

HULLS, BODIES, AND FRAMES

CHAPTER 35

VEHICLE STRUCTURE

Section I. WHEELED VEHICLES

35-1. Separate Frame and Body. The separate frame and body type of vehicle construction (fig. 35-1) is the most common technique used when producing most full-sized automobiles and cargo vehicles. In this type of construction, the chassis frame and the vehicle body are made separately and each is a complete unit by itself. The chassis frame is designed to support the weight of the body and absorb all of the loads imposed by the terrain, suspension system, powerplant, drive train, and steering system while the body merely contains and, in some cases, protects the cargo. The body generally is bolted to the frame at a few points to allow for flexure of the frame and to distribute the loads to the intended load-carrying members.

With this type of construction, the body structure only needs to be strong and rigid enough to contain the weight of the cargo and resist any dynamic loads associated with cargo handling and cargo movement during vehicle operation and to absorb shocks and vibrations transferred from the frame. In some cases, particularly under severe operating conditions, the body structure may be subjected to some torsional loads that are not absorbed completely by the frame; however, this is not common. This explanation basically applies to heavy trucks and not to passenger automobiles. In a typical passenger automobile, the frame supplies approximately 37 percent of the torsional rigidity and approximately 34 percent of the bending rigidity; the balance is supplied by the body structure. The following are the most important advantages of the separate body and frame construction.

a. Ease of mounting and dismounting of body structure.

b. Versatility; various body types can be adapted readily to standard truck chassis.

c. Strong, rugged designs are achieved easily, although at a penalty to vehicle weight.

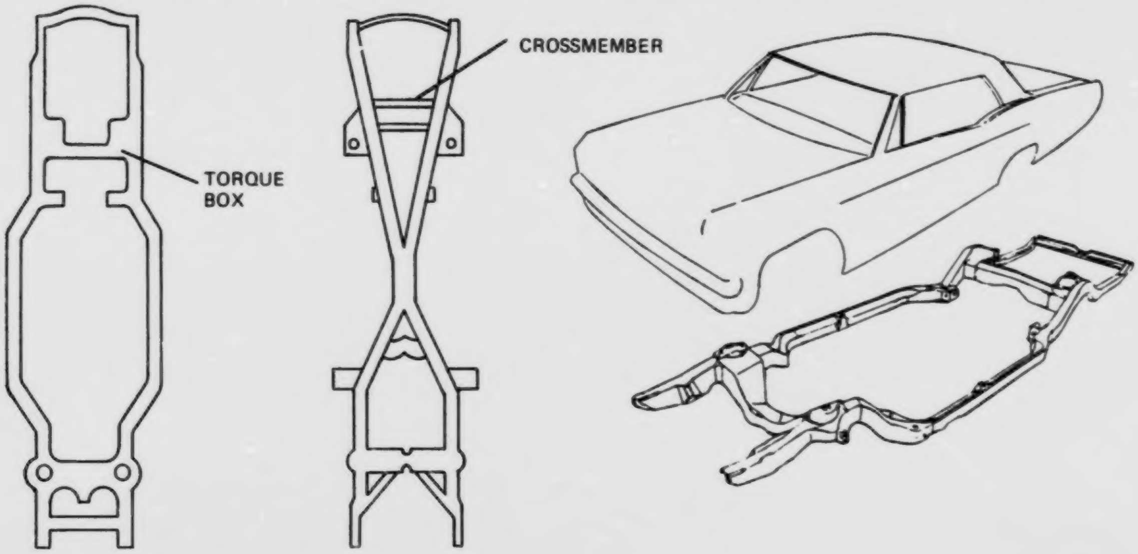


Figure 35-1. Separate Frame and Body.

TA233890

d. Isolation of noise generated by drive line components from crew and passenger compartments through the use of rubber mounts between frame and body structures.

e. Simplistic design that yields a relatively inexpensive and easy manufacturing process.

The separate body and frame has many advantages, as listed above, but along with this design, other criteria must be considered. The vehicle silhouette and cargo floor are higher. Weight is increased. This configuration also is inherently less desirable for amphibious vehicles, because it is less effective in developing maximum buoyancy for minimum weight.

35-2. Integrated Frame and Body (Monocoque). The integral frame and body type of construction (fig. 35-2), also referred to as unitized construction, combines the frame and body into a single, one-piece structure by welding components together, by forming or casting the entire structure as one piece, or by a combination of these techniques. Merely welding a conventional body to a conventional chassis frame, however, does not constitute an integral frame and body construction. In a truly integrated structure, the entire frame-body unit is treated as a load-carrying member that reacts to all the loads experienced by the vehicle-road loads as well as cargo loads.

Integral-type bodies for wheeled vehicles are fabricated by welding preformed metal panels together. The panels are preformed in various load bearing shapes that are located and oriented so as to result in a uniformly stressed structure. Some portions of the integrated structure resemble framelike parts, while others resemble body-like panels. This should not be surprising, because the structure must perform the functions of both of these elements.

The following are some of the advantages and disadvantages of the integral frame and body type of construction, when compared to the separate frame and body concept.

a. Substantial weight reduction, which is possible when using a well-designed unitized body.

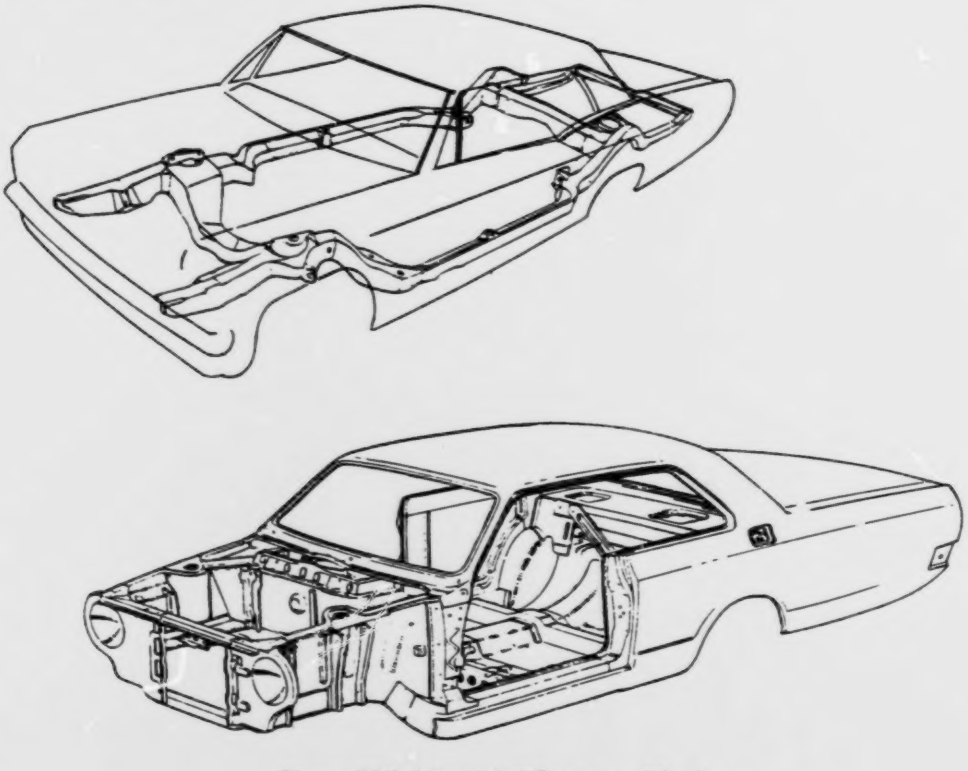


Figure 35-2. Integrated Frame and Body.

TA233891

b. Lower cargo floor and vehicle height.

c. Protection from mud and water required for drive-line components on amphibious vehicles.

d. Reduction in the amount of vibration present in the vehicle structure.

e. Increases in the amount of noise transmitted into the crew and passenger compartments.

f. Difficulties encountered when different body types are mounted on a basic chassis.

35-3. Truck Frame (Ladder). Trucks of up to 1-ton capacity have frames whose rear sections resemble a ladder. This type of frame (fig. 35-3) allows for different types of truck beds or enclosures to be attached to the frame. For larger trucks, the frames are simple, rugged, and of channel iron construction. The side rails usually are parallel to each other at standardized SAE widths to permit the mounting of stock transmissions, transfer assemblies, rear axles, and similar components. Trucks that are to be used as prime movers have an additional reinforcement of the side rails and rear crossmembers to compensate for the added towing stresses.

35-4. Brackets and Hangers. Frame members serve as supports to which springs, independent suspensions, radiators, or transmissions may be attached. Additional brackets, outriggers, engine supports, and horns are added for the mounting of running boards, longitudinal springs, bumpers, engines, towing hooks, shock absorbers, gas tanks, and spare tires.

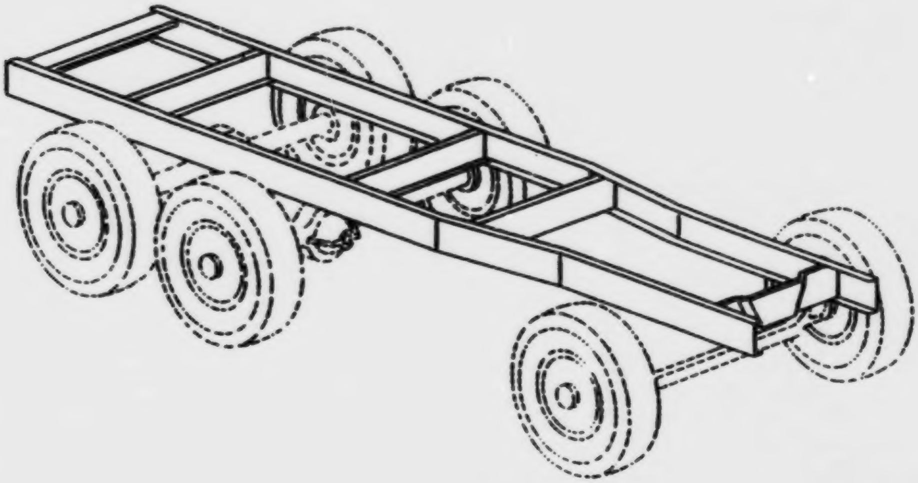


Figure 35-3. Truck Frame (Ladder).

TA233892

662

Section II. TRACKED VEHICLES

35-5. Armored Hulls of Tanks. The tank hull is the strongest and heaviest hull used on any vehicle. It must be fabricated to withstand ballistic shocks from high-velocity kinetic energy-type projectiles, the blast effects of high-explosive rounds and mines, and the penetrating effects of chemical energy rounds, and be rigid enough to provide a stable firing platform for the primary weapon system and fire control equipment. In addition, it must provide sufficient space in its interior to house the propulsion system, an adequate fuel supply, working space for the crew, and stowage space for ammunition and necessary supplies and equipment. The hull also must be small and light enough to have a reasonable degree of maneuverability and to be able to pass over and through standard traffic lanes, bridges, and overpasses.

Tank hulls of the type shown in figure 35-4 are one-piece castings of armor steel with a welded floor of rolled armor plate. They contain a driver's compartment in the front portion, a crew compartment at the center, and a compartment for the engine and transmission at the rear. The crew compartment is separated from the engine compartment by a steel bulkhead that is welded in place and serves as a firewall between the two compartments. Access doors and plates in this bulkhead provide access to the accessory end of the engine.

35-6. Unarmored Hulls and Self-Propelled Guns. There are, in general, two types of unarmored self-propelled guns. The first type, such as the M56, 90-mm self-propelled gun (fig. 35-5), is unarmored in order to achieve the weight restriction imposed by phase I airborne operations. These weapon systems provide close support and antitank capabilities to airborne operations. Although these vehicles are subjected to direct enemy fire, they rely on their speed and agility for their safety. As the airborne weight limitations are relaxed, due to improved aircraft, it is probable that future airborne assault weapons will be armored lightly. This type of vehicle hull will be required to have swimming capabilities as well as the capability to withstand the weapon firing loads.

The second type of unarmored self-propelled guns is large-caliber weapon systems employed primarily for counterbattery fire, the destruction of field works and reinforced concrete, interdiction fire, and to demoralize the enemy. This class of vehicles includes the 175-mm (fig. 35-5) and 8-inch howitzers. These vehicles do not require extensive armor, because they normally are employed far enough behind the battleline to encounter only long-range predicted fire weapon attacks. Furthermore, because the weapon weight for this type of vehicle is large, the addition of armor would degrade their mobility seriously. The prime hull design consideration for this type of vehicle is the weapon firing reaction load.

35-7. Wheeled Amphibian Hulls. Wheeled amphibious vehicles have both a hull and a frame. Designed to provide buoyancy necessary for flotation, the basic hull assembly is of all-steel, watertight, welded construction, with reinforcements to add to its rigidity. It is built to accept the chassis frame and powerplant. The frame, similar to a conventional truck frame, is installed inside and is bolted to the hull. The powerplant and power train are supported by the frame. The running gear, underneath the hull, is attached to both the hull and frame.

35-8. Tracked Amphibian Hulls. The hull of tracked landing vehicles is defined as the framework of the vehicle, together with all inside and outside plating but exclusive of equipment. It is the main, or central, section that runs from front to rear; it consists of the cab, cargo compartment, and engine room. Technically, a part of the hull are the pontons that are welded to each side of it. Engines, controls, armament, and driving assemblies are housed in, or mounted on, the main hull.

663

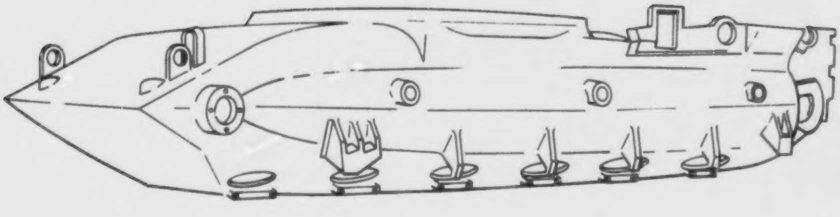
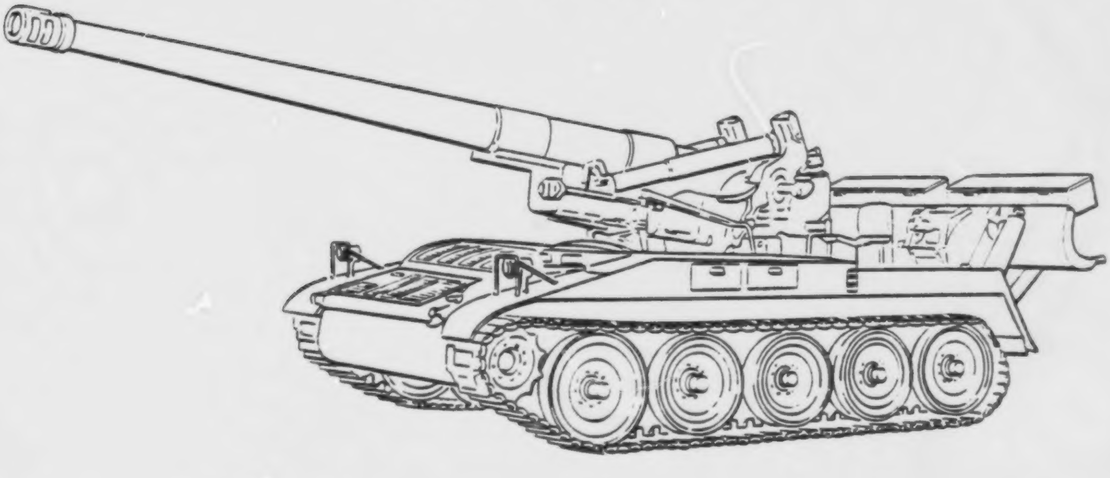
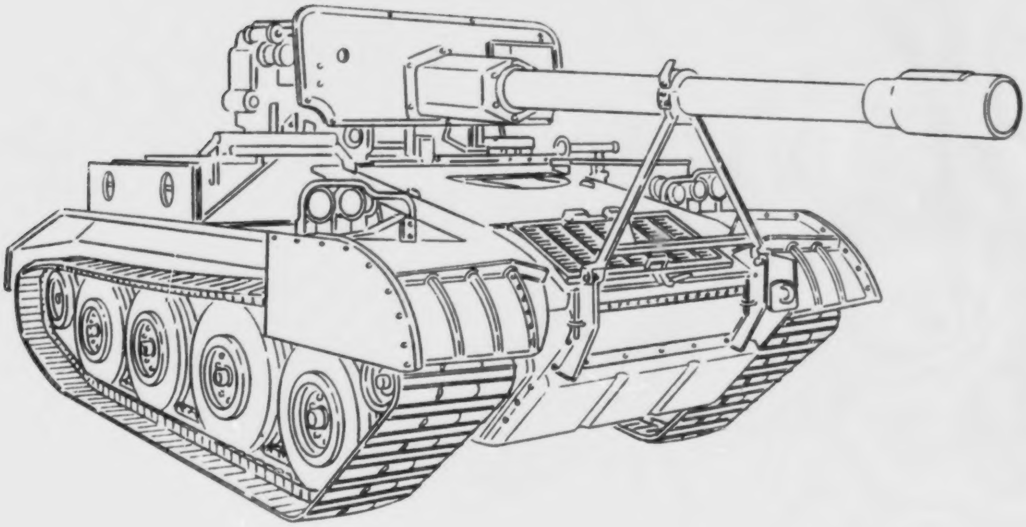


Figure 35-4. Typical Tank Hull.





UNARMORED SELF-PROPELLED GUNS

Figure 35-5. Unarmored Hulls.

TA233893

664

CHAPTER 36

ACCESSORIES

Section I. POWER TAKEOFF

36-1. Purpose. A power takeoff is an attachment for connecting the engine to power-driven auxiliary machinery when its use is required. It is attached to the transmission, auxiliary transmission, or transfer case. A power takeoff installed at the left side of a transmission is shown in figure 36-1. It is used to drive a winch, located at the front of the truck, through a universal joint and propeller shaft.

36-2. Construction. The simplest type of transmission power takeoff is the single-gear, single-speed type shown in figures 36-2 and 36-3. This unit is bolted over an opening provided for the purpose at the side of the transmission case. This opening is closed by a cover plate when no power takeoff is used. The opening in the transmission case and the power takeoff gear meshes with a gear on the transmission countershaft. As shown in figure 36-2, the gear slides on the splined main shaft, off which the power is taken. The shifter shaft, controlled by a lever in the driver's cab, slides the gear in and out of mesh with the countershaft gear. Since it is driven by the countershaft, the power takeoff shaft rotates in the same direction as the engine crankshaft.

36-3. Main Transmission Power Takeoffs. Transmission power takeoffs are available in several different designs: a single-speed, two-gear model in which the rotation of the power takeoff shaft is opposite to that of the engine; a model having a single speed forward and reverse; and a model having two speeds forward and one reverse. Several different mountings also are available.

36-4. Auxiliary Transmission Power Takeoffs. The same types of power takeoffs also are applied to auxiliary transmissions. Figure 36-4 shows a winch driven off an auxiliary transmission.

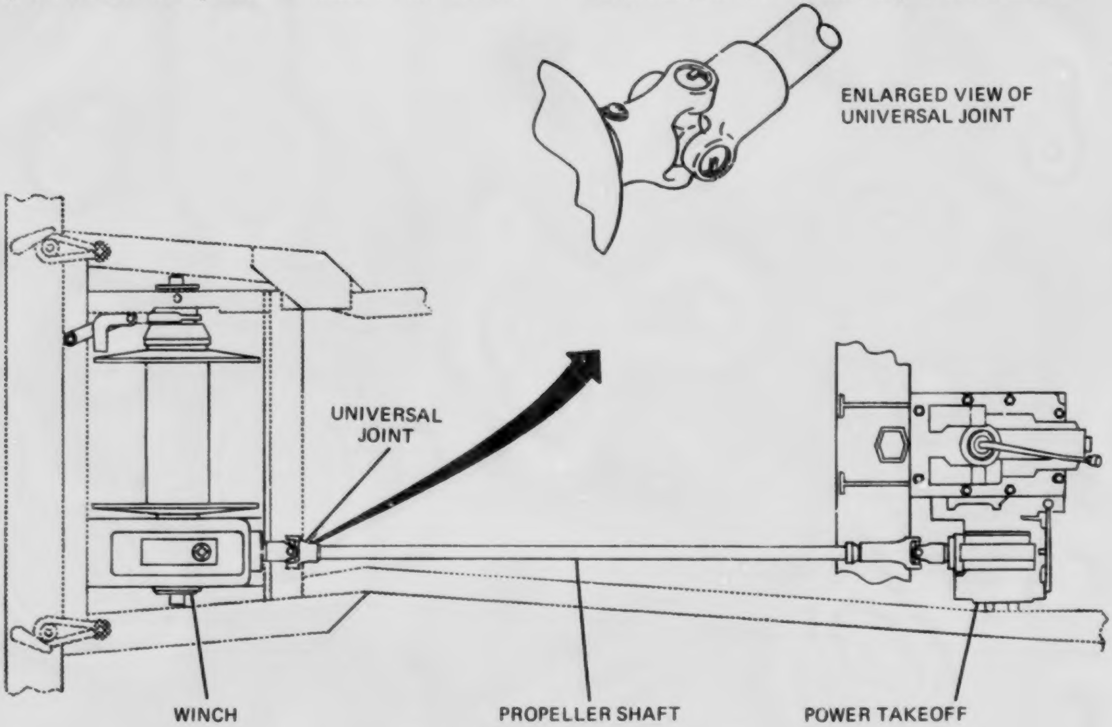


Figure 36-1. Winch and Power Takeoff Installation.

TA233894

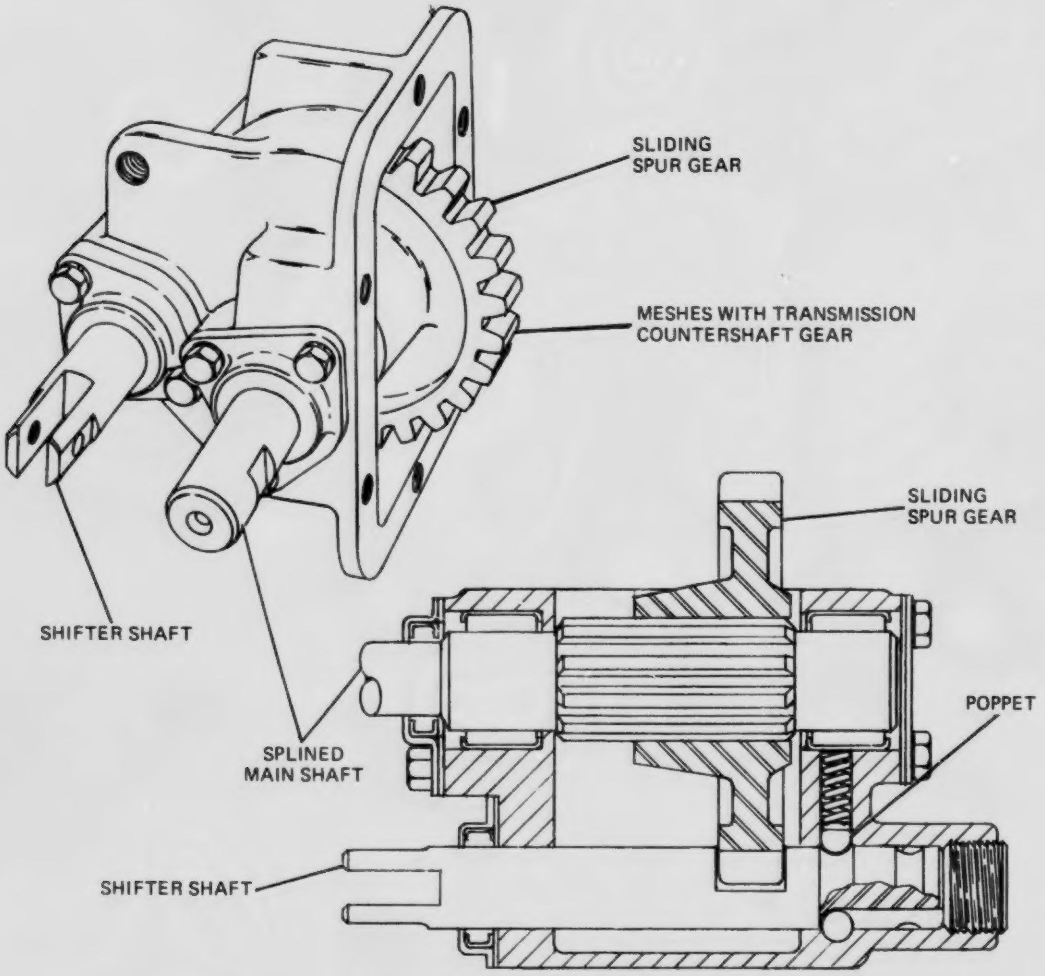

SLIDING SPUR GEAR
MESHES WITH TRANSMISSION COUNTERSHAFT GEAR
SHIFTER SHAFT
SPLINED MAIN SHAFT
SLIDING SPUR GEAR
POPPET
SHIFTER SHAFT

Figure 36-2. Single-Speed, Single-Gear Power Takeoff.

36-5. Transfer Case Power Takeoff. Power sometimes is taken off a transfer case. The transfer case drive shaft, which is connected to the transmission, extends through the case, and the power takeoff shaft is engaged to it by a dog clutch. This transfer case has two speeds and a neutral position. It is necessary to put the transfer case sliding gear in the neutral position if the vehicle is to be stationary while the power takeoff is in use. If the power takeoff is needed while the vehicle is in motion, the transfer case may be shifted either into high or low range. With this arrangement, the power takeoff will work on any speed of the transmission. The positions of all the cab control levers of one model of vehicle are shown in figure 36-5 as they are placed on the instruction plate in the cab. When the power takeoff clutch is engaged, the winch capstan operates; but the winch drum does not rotate until the winch clutch is engaged.

36-6. Usage. The several types of power takeoffs have been described as operating winches, but their uses for operating various kinds of hoists, pumps, and other auxiliary power-driven machinery are essentially the same.

TA233895

666

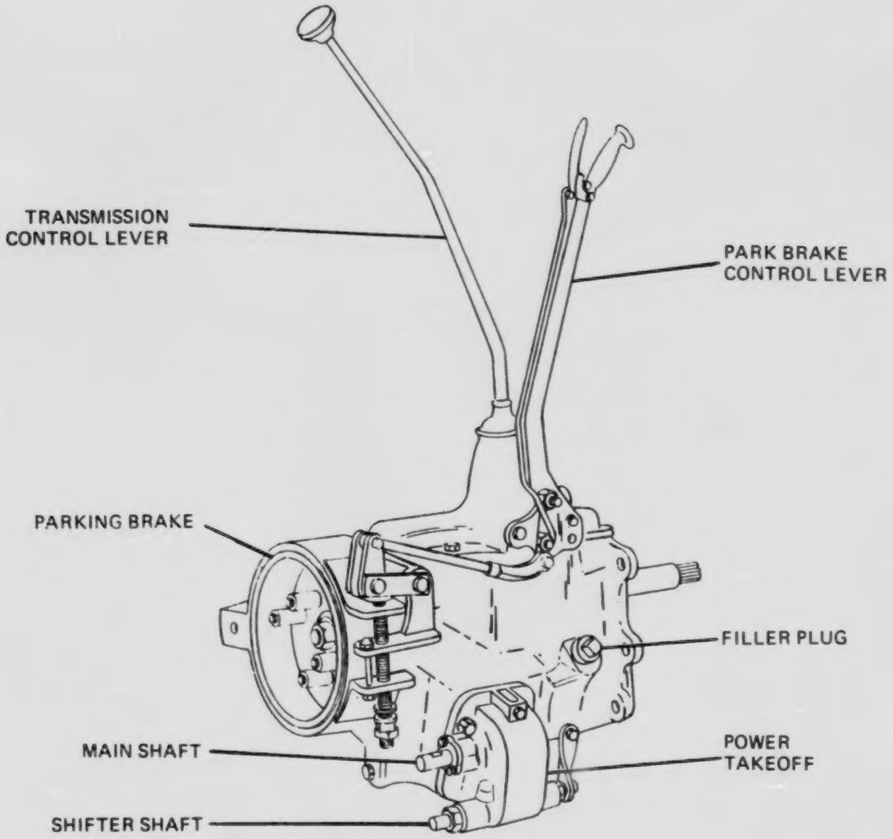

TRANSMISSION CONTROL LEVER
PARK BRAKE CONTROL LEVER
PARKING BRAKE
FILLER PLUG
MAIN SHAFT
POWER TAKEOFF
SHIFTER SHAFT

Figure 36-3. Single-Speed, Single-Gear Power Takeoff Installation.

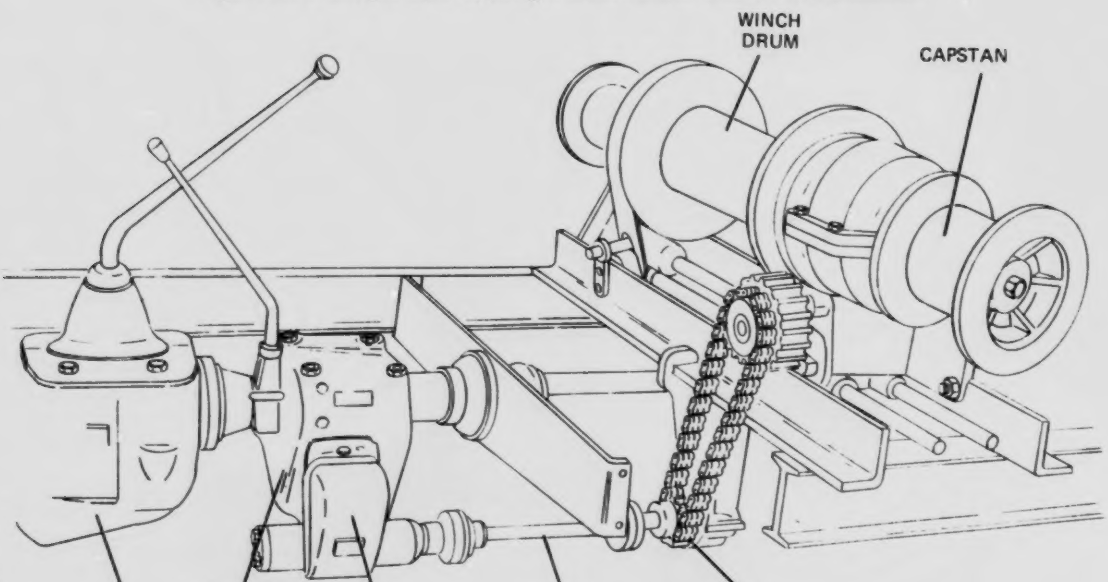
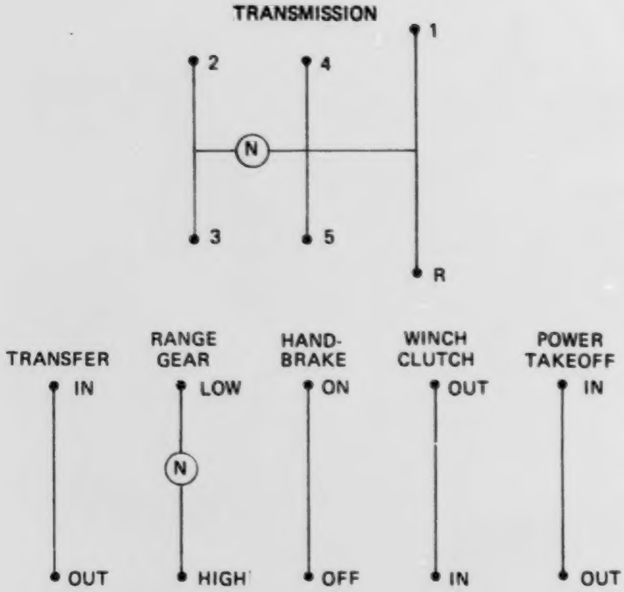

WINCH DRUM
CAPSTAN
TRANSMISSION
AUXILIARY TRANSMISSION
POWER TAKEOFF
WINCH PROPELLER SHAFT
WINCH CHAIN

Figure 36-4. Auxiliary Transmission Power Takeoff Driving Winch.

TA233896

667



DISENGAGE THE FRONT AXLE DRIVE WHEN OPERATING ON DRY HARD SURFACE ROADS

Figure 36-5. Typical Positions of Transfer and Power Takeoff Control Levers for Two-Speed Transfer Assembly with Power Takeoff.

Section II. WINCHES

36-7. Purpose. Using its winch and some type of rigging, a vehicle can pull itself or another vehicle through such obstacles as very muddy or very rough terrains. This is the primary reason for providing winches on standard military vehicles. The winch in this case is powered by the engine of the vehicle through a power takeoff from the transmission. Field expedients may utilize the winch for such devices as simple cranes in a field shop. However, on special equipment and vehicles, winches are furnished for special purposes such as powering the crane of a wrecker. Some of these latter winches are powered by separate gasoline engines.

36-8. Mounting. Generally, the winch is mounted behind the front bumper and is secured to the front crossmember of the frame or between the two side frame rails. It may be mounted behind the cab. The tandem winch assembly, for example, consists of a front (upper) and rear (lower) winch that is secured to a mounting assembly fastened to the chassis frame at the rear of the cab.

36-9. Operation. The typical front-mounted winch is a jaw-clutch worm-gear type. The winch consists of a worm and shaft which drives a worm gear that is keyed to a shaft (fig. 36-6). A bushed drum is mounted on the worm-gear shaft which is controlled by a sliding clutch. The wormshaft is driven by a drive shaft connected to a power takeoff unit mounted on the transmission. The hand-operated sliding clutch is keyed to the worm-gear shaft outside of the winch drum, and must be engaged with the jaws on the side of the winch drum when the winch is to be operated. Disengagement of the sliding clutch permits the drum to turn on the worm-gear shaft. Two brakes are provided to control the winch drum. The wormshaft brake prevents the winch drum from rotating under load, when the power takeoff is disengaged. The shifter bracket brake prevents the drum overrunning the cable when the cable is being unreeled. A shearpin on the worm drive shaft prevents damage from overloading. The power takeoff is controlled by a shift lever located in the driver's compartment.

TA233897

668

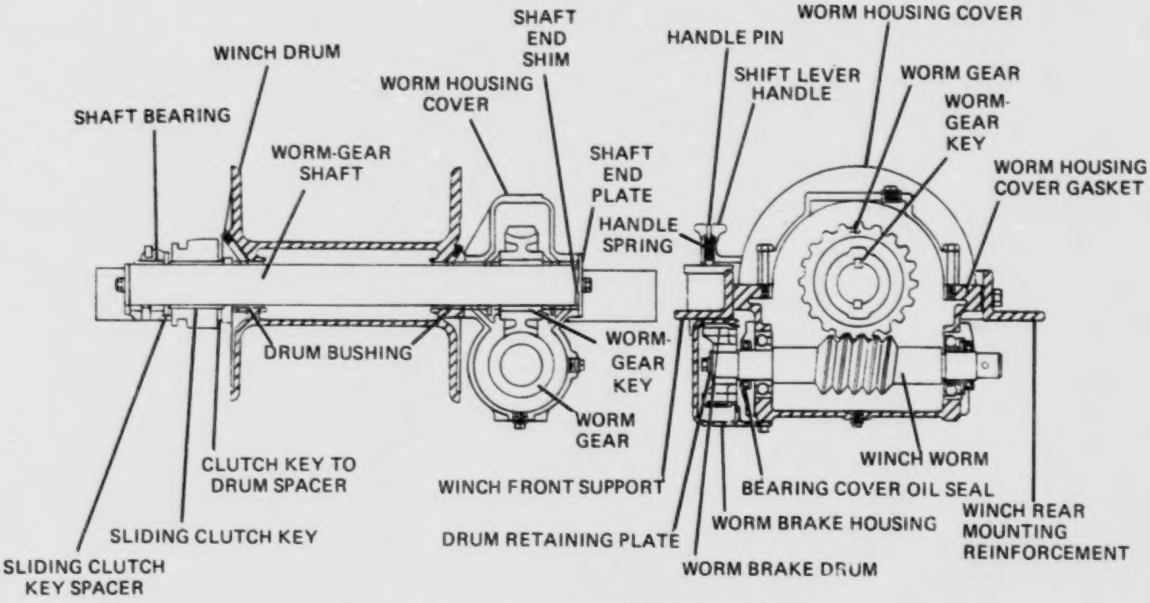

SHAFT END SHIM
WORM HOUSING COVER
HANDLE PIN
WINCH DRUM
SHIFT LEVER HANDLE
WORM GEAR
WORM HOUSING COVER
WORM-GEAR KEY
SHAFT BEARING
WORM-GEAR SHAFT
SHAFT END PLATE
WORM HOUSING COVER GASKET
HANDLE SPRING
DRUM BUSHING
WORM-GEAR KEY
WORM GEAR
CLUTCH KEY TO DRUM SPACER
WINCH FRONT SUPPORT
WINCH WORM
BEARING COVER OIL SEAL
WINCH REAR MOUNTING REINFORCEMENT
SLIDING CLUTCH KEY
DRUM RETAINING PLATE
WORM BRAKE HOUSING
SLIDING CLUTCH KEY SPACER
WORM BRAKE DRUM

Figure 36-6. Jaw-Clutch Worm-Gear Winch.

36-10. Level Wind Winches. Some winches may be equipped with an automatic level winding device to spool the cable on the drum in tight, even coils and layers. This prevents crushing of the cable due to loose crossed coils and layers, and it allows off leads of the cable while maintaining level winding.

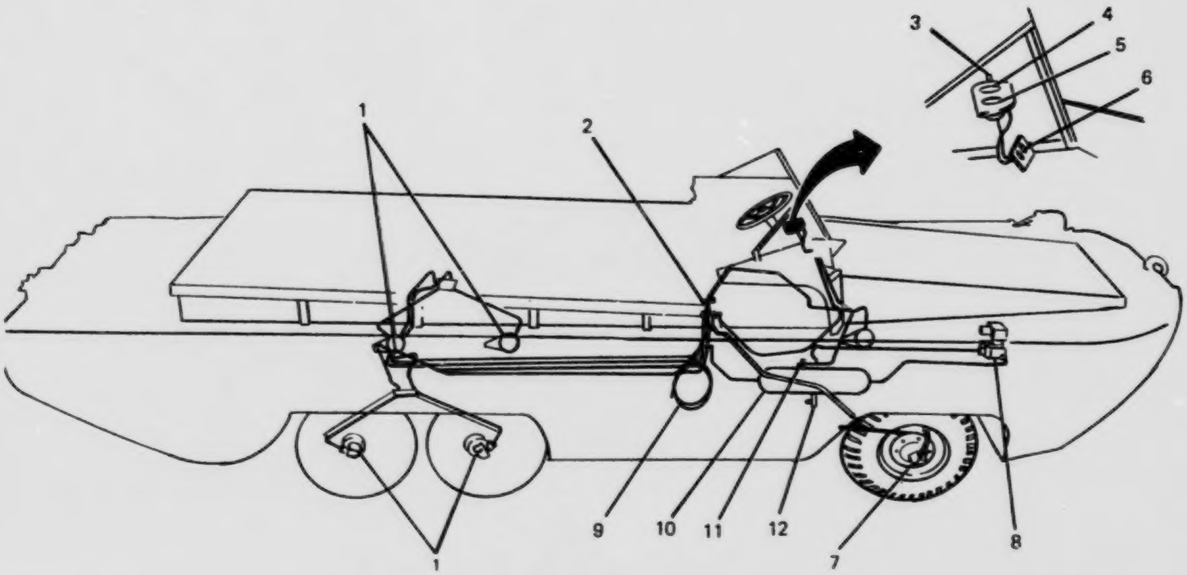
Section III. TIRE INFLATION SYSTEM

36-11. Purpose. Amphibious trucks are equipped with a central tire-pressure control system, by means of which the tires may be inflated or deflated to meet various conditions encountered by the vehicle. When operating on sand, the tires are deflated to obtain adequate flotation; to travel on a hard surface, the tires are inflated.

36-12. Construction. Location of each component of the system is shown in figure 36-7. A two-cylinder, water-cooled, self-lubricated pump with a capacity of 9 cfm is mounted in the front compartment and driven directly by the engine crankshaft. This maintains pressure in the air tank. It is controlled by a governor that stops the pump when maximum allowable pressure is attained and automatically starts the pump when pressure in the tank drops below a prescribed limit. Air pressure is piped from the tank to the inflation and deflation control valves assembly.

When the control valve lever is placed in the INFLATE position, air passes through the valve to the air line manifold and valves, then to each tire, and through individual air lines and tire inflating devices. A safety valve is located in the system. The tire-inflating device, or hub device, is mounted on each wheel hub. It is an airtight rotary joint that provides a connection between the air supply line and the tire. The inner part rotates with the wheel hub while the outer part is held stationary by a swivel-ended strut attached to the hull.

TA233898



1 – REAR TIRE INFLATING DEVICES
2 – AIR LINE MANIFOLD AND VALVES ASSEMBLY
3 – TIRE INFLATING CONTROL LEVER
4 – TANK PRESSURE AIR GAGE
5 – TIRE PRESSURE AIR GAGE
6 – TIRE INFLATION AND DEFLATION CONTROL VALVES
7 – FRONT TIRE INFLATING DEVICES
8 – TIRE PUMP
9 – TIRE INFLATING HOSE
10 – AIR TANK
11 – SAFETY VALVE
12 – DRAINCOCK

Figure 36-7. Location of Central Tire-Pressure Control System Components.

Section IV. GASOLINE AND WATER TANKERS

36-13. General. Water and gasoline may be transported in tank trucks (fig. 36-8) or in tank semitrailers (fig. 36-9). Tank trucks have a special accessory drive unit mounted on the power takeoff to drive the pump. Tank semitrailers have a portable pump driven by a small gasoline engine.

36-14. Semitrailer Tank. The locations of the portable pump and hose with which the tank semitrailers are equipped are shown in figure 36-10. The portable pump is shown in figure 36-11. The pump can be used to unload or load the tank, depending on which way the hose connections are made to the pump and tank. The pump shown is driven by a single-cylinder, four-stroke cycle gasoline engine.

36-15. Tank Truck (Fig. 36-8). On the tank truck, the power takeoff, which is mounted on the transfer assembly, contains a pump drive. When the driver positions the controls, the pumping equipment is set into operation. At the same time, an auxiliary engine governor comes into action to properly limit engine speed during the time that the pumping equipment is operated. This prevents overspeeding of the engine.

36-16. Considerations of Pumping Gasoline. Extreme care must be used when handling gasoline because it is very flammable. Vapor from gasoline, even in the open, may become sufficiently concentrated during pumping operations to explode and bring about a disastrous fire. Smoking or open flames must not be permitted in the vicinity of fuel pumping operations. See complete instructions on handling gasoline in applicable technical manuals.

TA233899

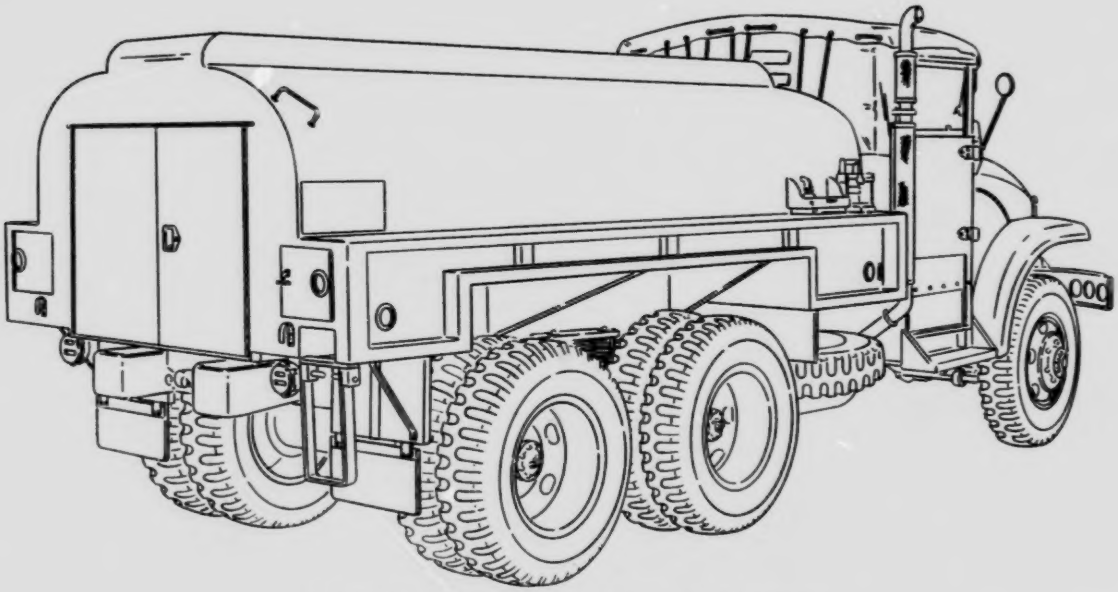


Figure 36-8. 2 1/2-Ton 6 x 6 Gasoline Tank Truck.

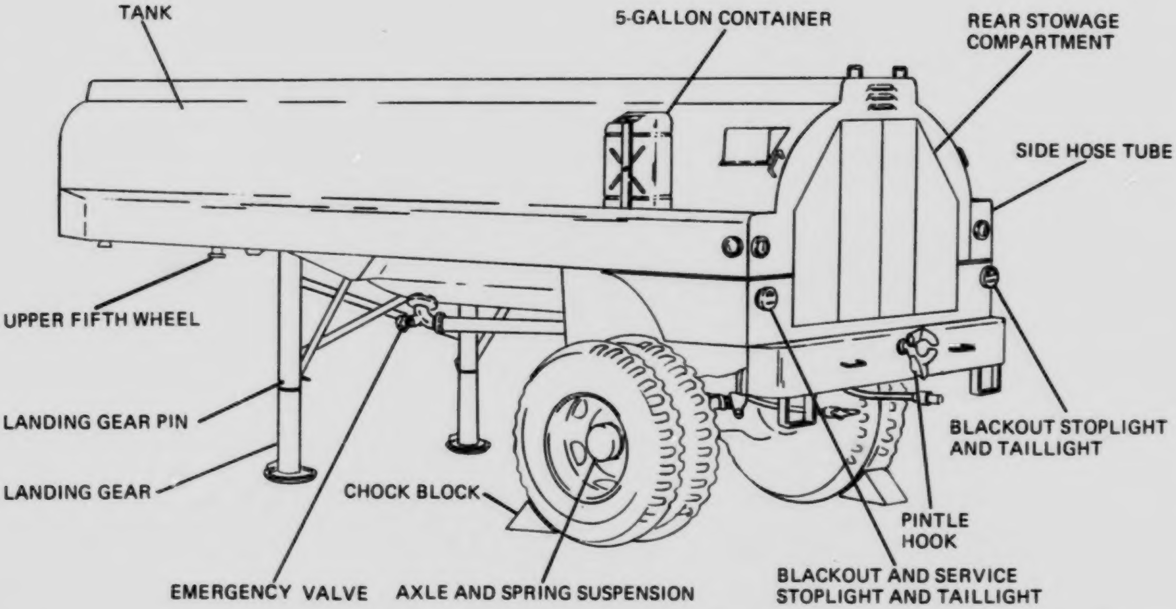

TANK
5-GALLON CONTAINER
REAR STOWAGE COMPARTMENT
SIDE HOSE TUBE
UPPER FIFTH WHEEL
LANDING GEAR PIN
LANDING GEAR
CHOCK BLOCK
BLACKOUT STOPLIGHT AND TAILLIGHT
PINTLE HOOK
BLACKOUT AND SERVICE STOPLIGHT AND TAILLIGHT
EMERGENCY VALVE
AXLE AND SPRING SUSPENSION

Figure 36-9. 2000-Gallon Tank Semitrailer.

TA233900

671

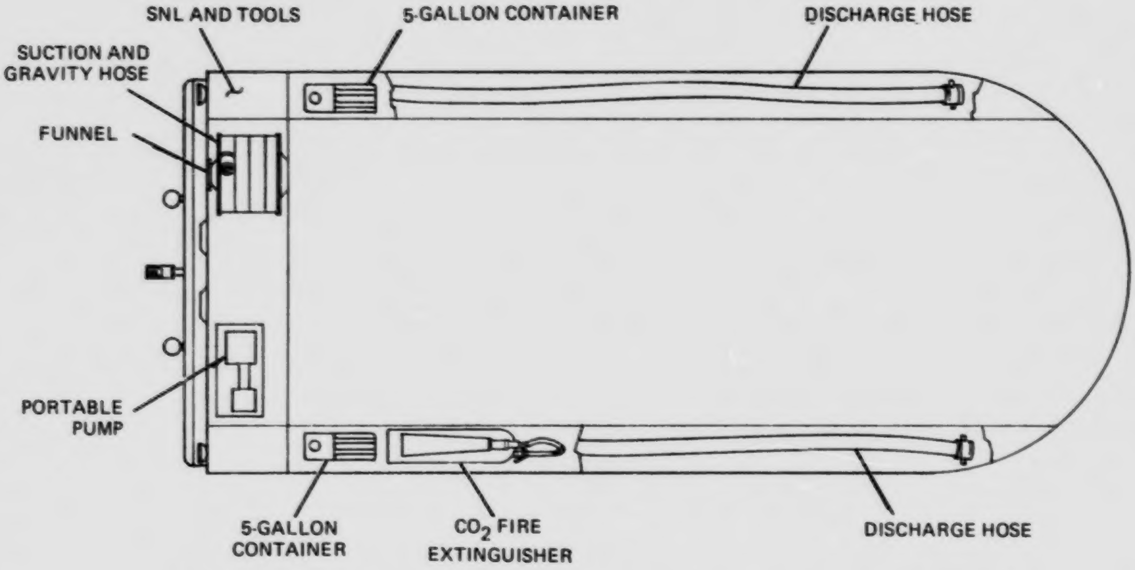

SNL AND TOOLS
5-GALLON CONTAINER
DISCHARGE HOSE
SUCTION AND GRAVITY HOSE
FUNNEL
PORTABLE PUMP
5-GALLON CONTAINER
CO_2 FIRE EXTINGUISHER
DISCHARGE HOSE

Figure 36-10. Location of Portable Pump and Hose in Tank Semitrailer.

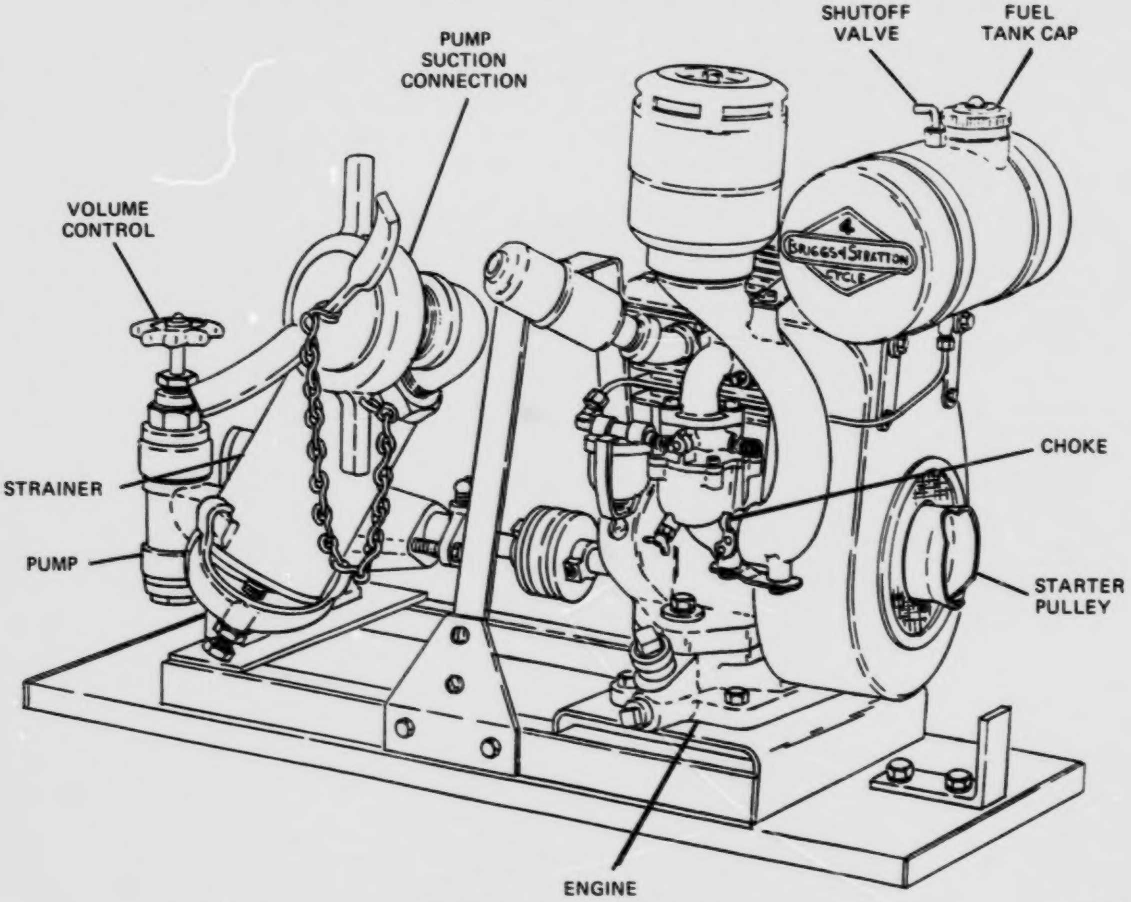

SHUTOFF VALVE
FUEL TANK CAP
PUMP SUCTION CONNECTION
VOLUME CONTROL
STRAINER
PUMP
CHOKE
STARTER PULLEY
ENGINE
BRIGGS & STRATTON
4 CYCLE
TA233901

Figure 36-11. Portable Pump.

672

BEST COPY AVAILABLE

Section V. DUMP TRUCK MECHANISMS

36-17. General. Dump trucks (fig. 36-12) have a steel body that pivots at the rear. The dump body pivots on two hinge pins when it is raised by a hydraulic hoist cylinder mounted on a transverse base shaft. The pressure developed in the hydraulic hoist cylinder by the operation of a special pump causes the dump body to move up into the position shown in figure 36-13. Since the hydraulic cylinder is double acting, it also is used to hold or lower the dump body. The endgate (fig. 36-14) normally is pivoted at the top, and is secured in this position by lockpins through endgate upper latches. Lower latches hold the endgate closed until they are released by the hand lever on the front left corner of the body. The endgate is released for dumping in this manner, and the extent that it opens is controlled by adjustment of the chains in the locking slots (fig. 36-14).

36-18. Body Control Box. A dump body control lever in the rear and at the left of the driver's seat operates a shift control lever connected by linkage to a control box. Figure 36-15 shows the control lever, while figure 36-16 shows the linkage between the control lever, the control box, and the power takeoff. The body control box contains two cams that move as the control lever is moved; this causes the dump body to raise, hold, or lower, according to the control lever position.

36-19. Dump Body Control Lever (Fig. 36-15). The dump body control lever, located in the cab, has four positions. In position A, the body is down and the power takeoff is disengaged. When the control lever is moved to position B, the forward arm in the control box is engaged and the shift linkage engages the power takeoff. To raise the body, the control lever is moved forward past position C to position D. The lift can be stopped and the body held in any position by returning the control lever to position C. With the lever at position B or D, the body is automatically checked at either the up or down position at the limit of travel.

36-20. Control Valve and Pump. When the power takeoff is engaged, the pump is driven. It can now deliver hydraulic fluid to the hydraulic cylinder, provided the control valve is properly positioned. The control valve is linked to the control lever (fig. 36-15). When the control lever is moved to position D, the control valve directs the hydraulic

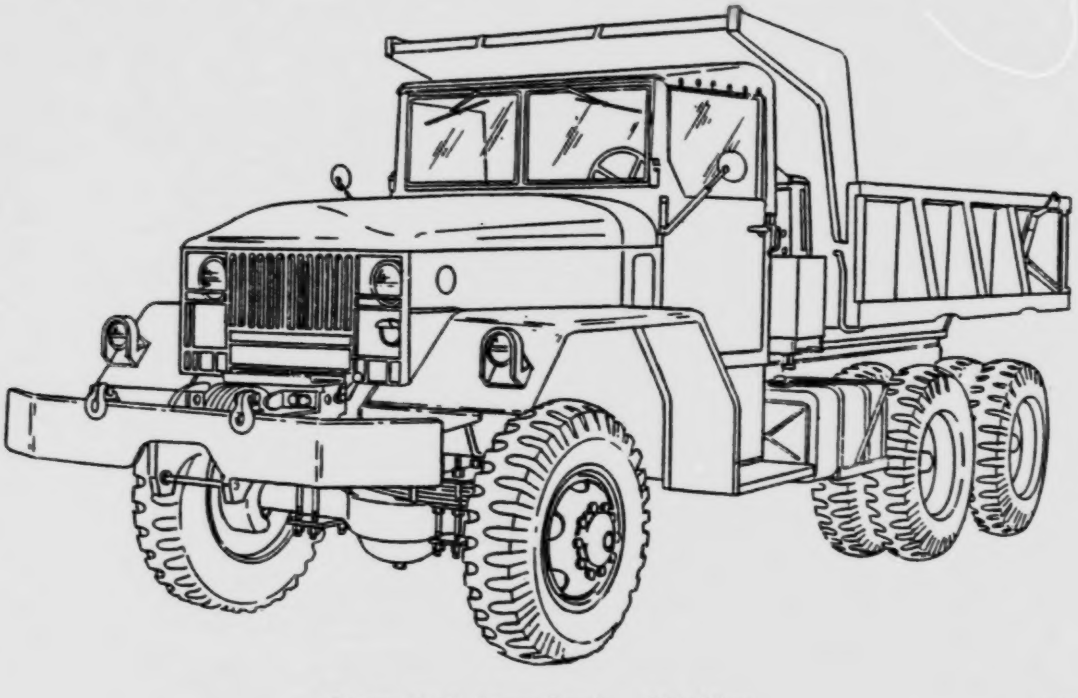


Figure 36-12. Dump Truck – Side View.

TA233902

673

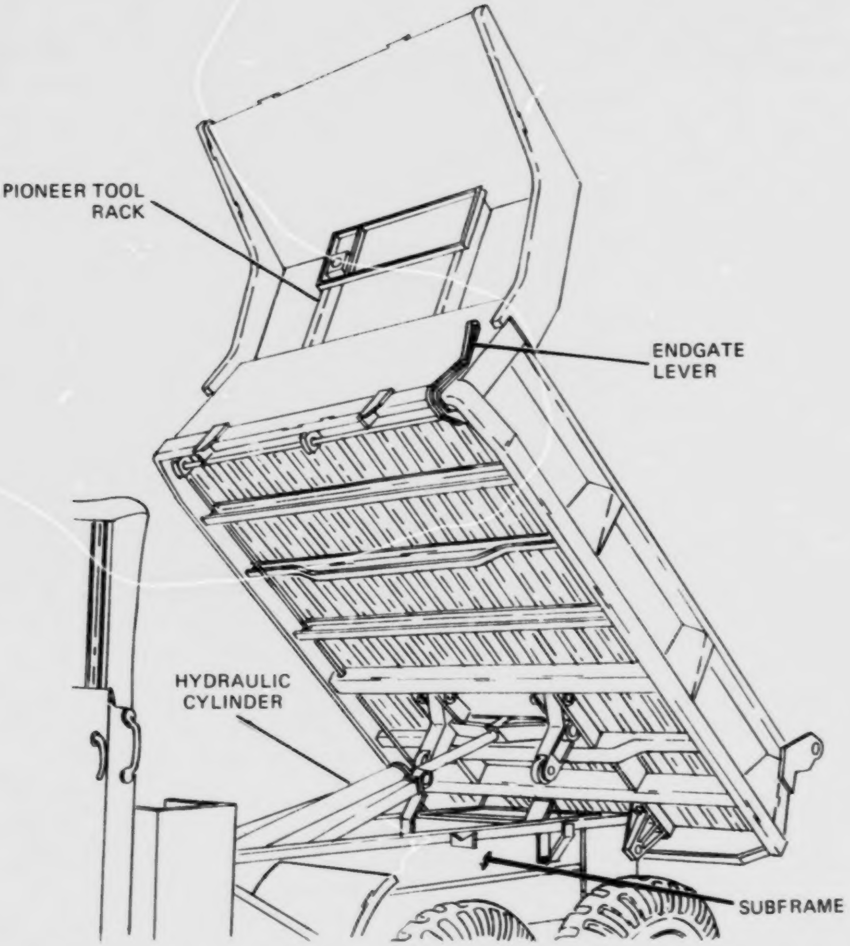

PIONEER TOOL RACK
ENDGATE LEVER
HYDRAULIC CYLINDER
SUBFRAME

Figure 36-13. Dump Body – Raised.

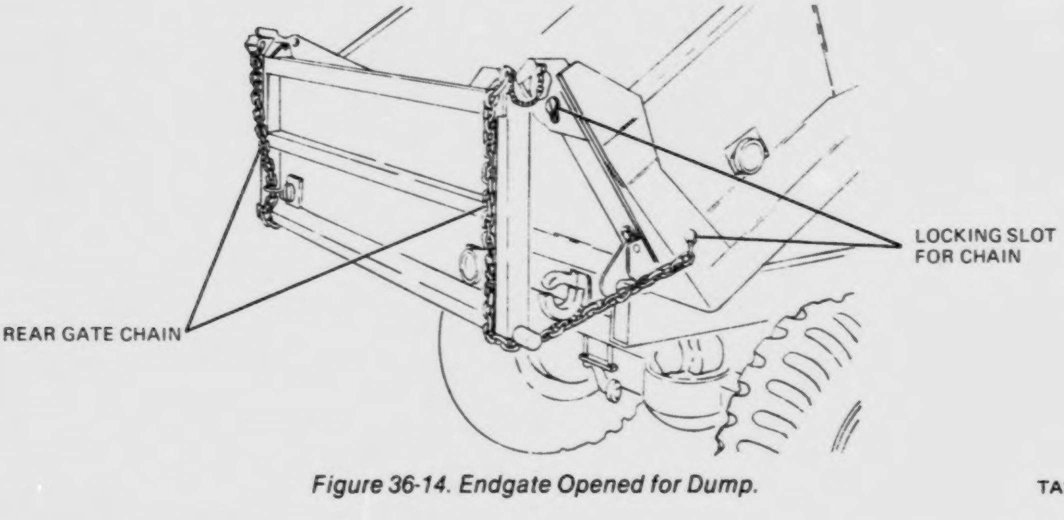

LOCKING SLOT FOR CHAIN
REAR GATE CHAIN

Figure 36-14. Endgate Opened for Dump.

TA233903

674

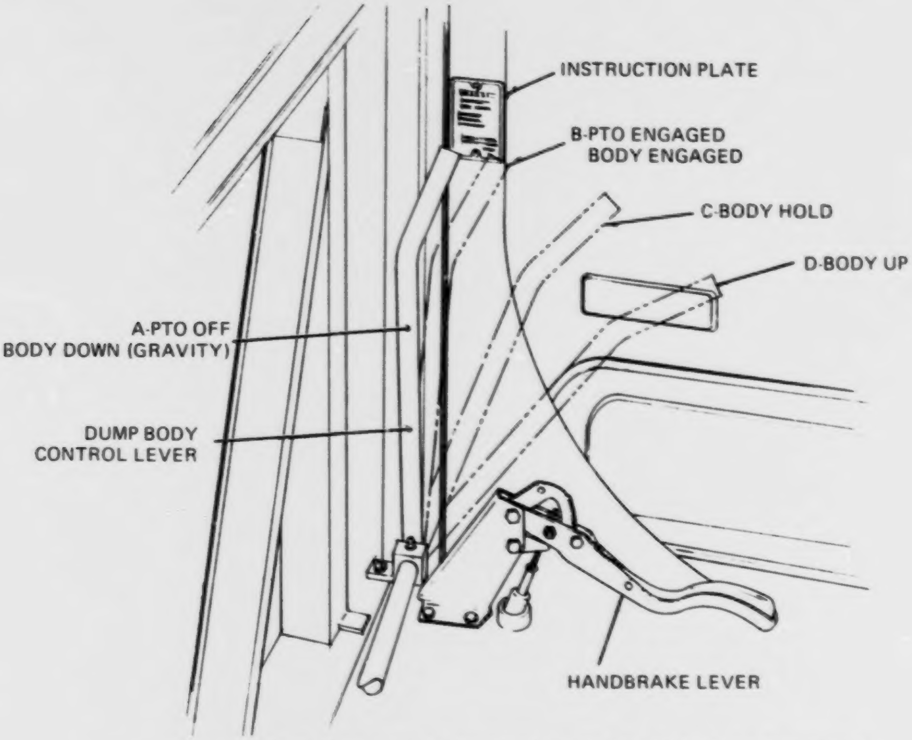

INSTRUCTION PLATE
B-PTO ENGAGED BODY ENGAGED
C-BODY HOLD
D-BODY UP
A-PTO OFF BODY DOWN (GRAVITY)
DUMP BODY CONTROL LEVER
HANDBRAKE LEVER

Figure 36-15. Dump Body Control Lever (Driver's Seat Removed).

fluid from the pump into the front, or elevating, end of the hydraulic cylinder. The hydraulic pressure forces the piston and piston rod toward the rear of the truck. This raises the dump truck body.

36-21. Hydraulic Cylinder. The hydraulic cylinder is double acting and is mounted in the forward part of the truck subframe. The cylinder base is mounted on a shaft held in bearings on the inner sides of the subframe. The piston rod is connected to a crosshead, which is pivoted with a roller arm on each end. Arms are supported by bearing pins on the bottom of the body. The free ends of the arms are equipped with rollers, which engage curved ramps attached to the sides of the subframe. The movement of the piston rod, carried through the arms and rollers to the ramps, raises the body.

TA233904

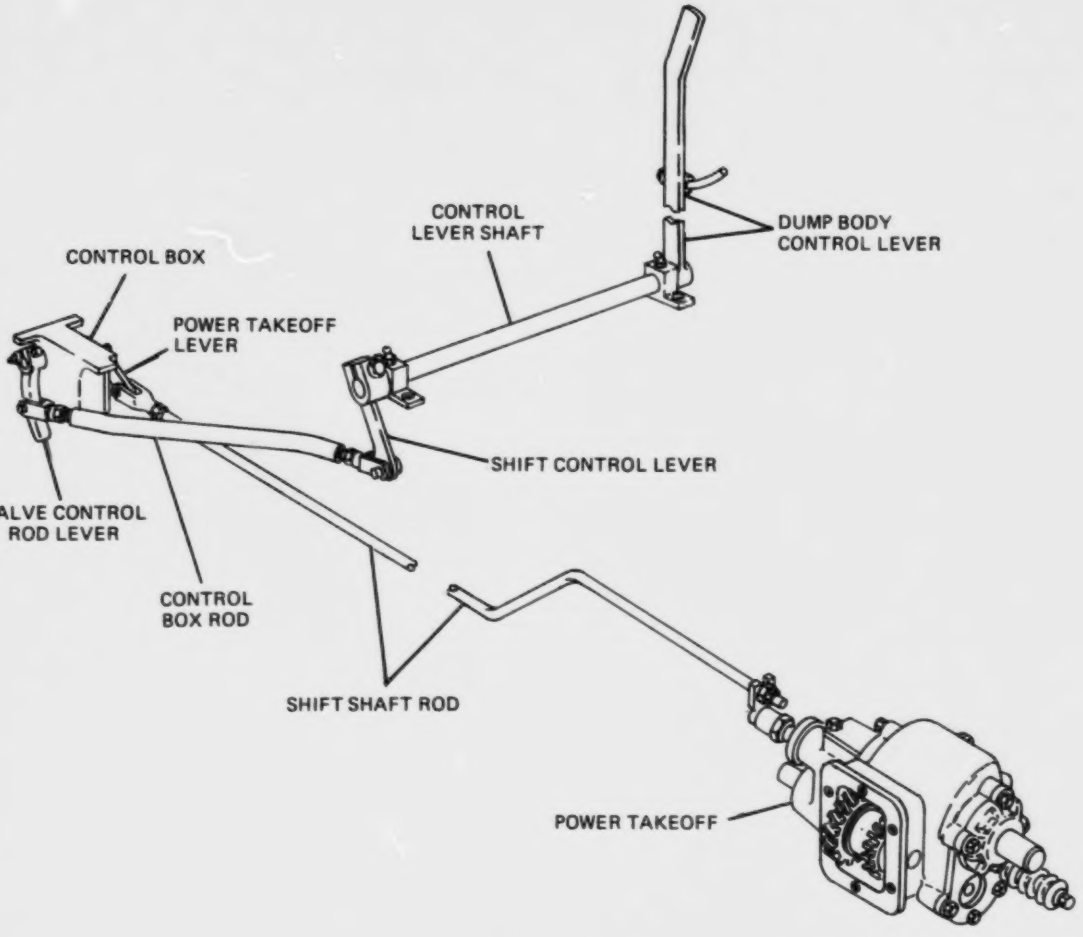

CONTROL BOX
CONTROL LEVER SHAFT
DUMP BODY CONTROL LEVER
POWER TAKEOFF LEVER
SHIFT CONTROL LEVER
VALVE CONTROL ROD LEVER
CONTROL BOX ROD
SHIFT SHAFT ROD
POWER TAKEOFF

Figure 36-16. Control Linkage Between Control Lever, Control Box, and Power Takeoff.

Section VI. WRECKER TRUCK EQUIPMENT

36-22. General. Wrecking trucks (fig. 36-17) include front and rear winches and a crane assembly. Winches are described in paragraph 36-7. The crane assembly consists of a combination of units, all mounted on the crane A-frame (fig. 36-18). The units include the boom, boom pivot and controls, topping pivot, boom winch and controls, crane winch, crane winch drive and controls, crane winch transmission, and center propeller shaft with connecting parts. All of these units are essential to the operation of the crane. There are other units mounted on the A-frame which are not part of the crane, including the rear winch, rear winch drive, rear winch transmission, and front winch jaw clutch.

36-23. Operation. The various mechanisms incorporated in the crane are driven by the engine through a center propeller shaft. The main drive chain (fig. 36-19) carries the driving power from the propeller shaft to the hoist gearcase, boom gearcase, and swinger gearcase input sprocket. Each gearcase has its own control lever and control system. With these controls, the boom may be raised or lowered, it may be pivoted, and the crane winch can be made to rotate in one direction or the other in order to raise or lower the load.

TA233905

676

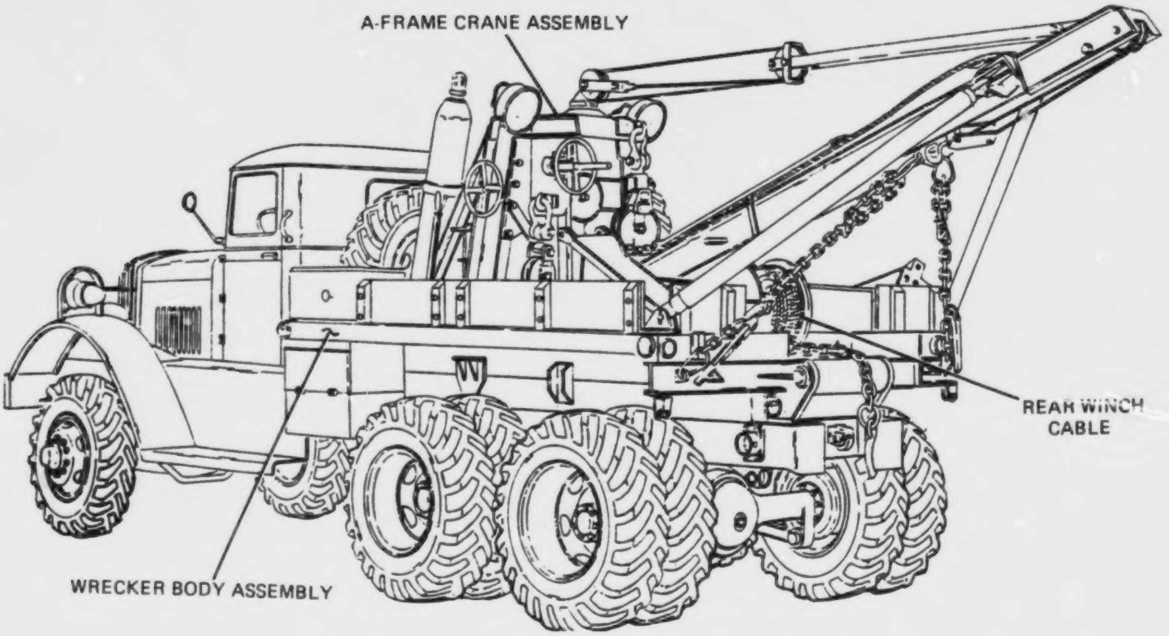

A-FRAME CRANE ASSEMBLY
REAR WINCH CABLE
WRECKER BODY ASSEMBLY

Figure 36-17. Crane Assembly on Wrecking Truck.

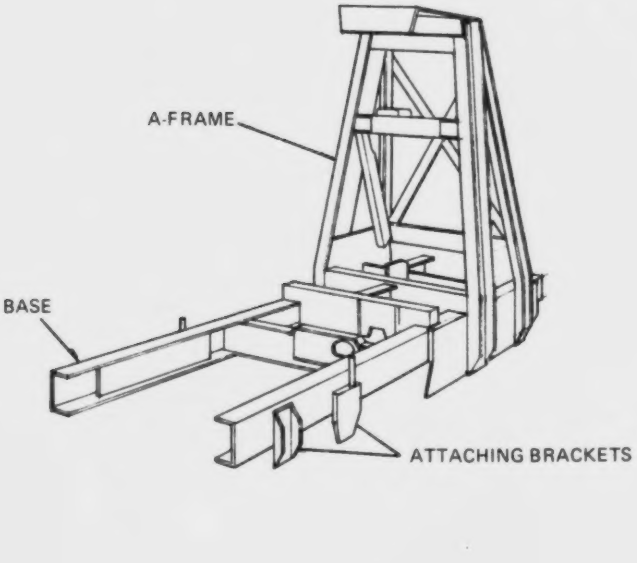

A-FRAME
BASE
ATTACHING BRACKETS

Figure 36-18. Crane A-Frame.

TA233906

677

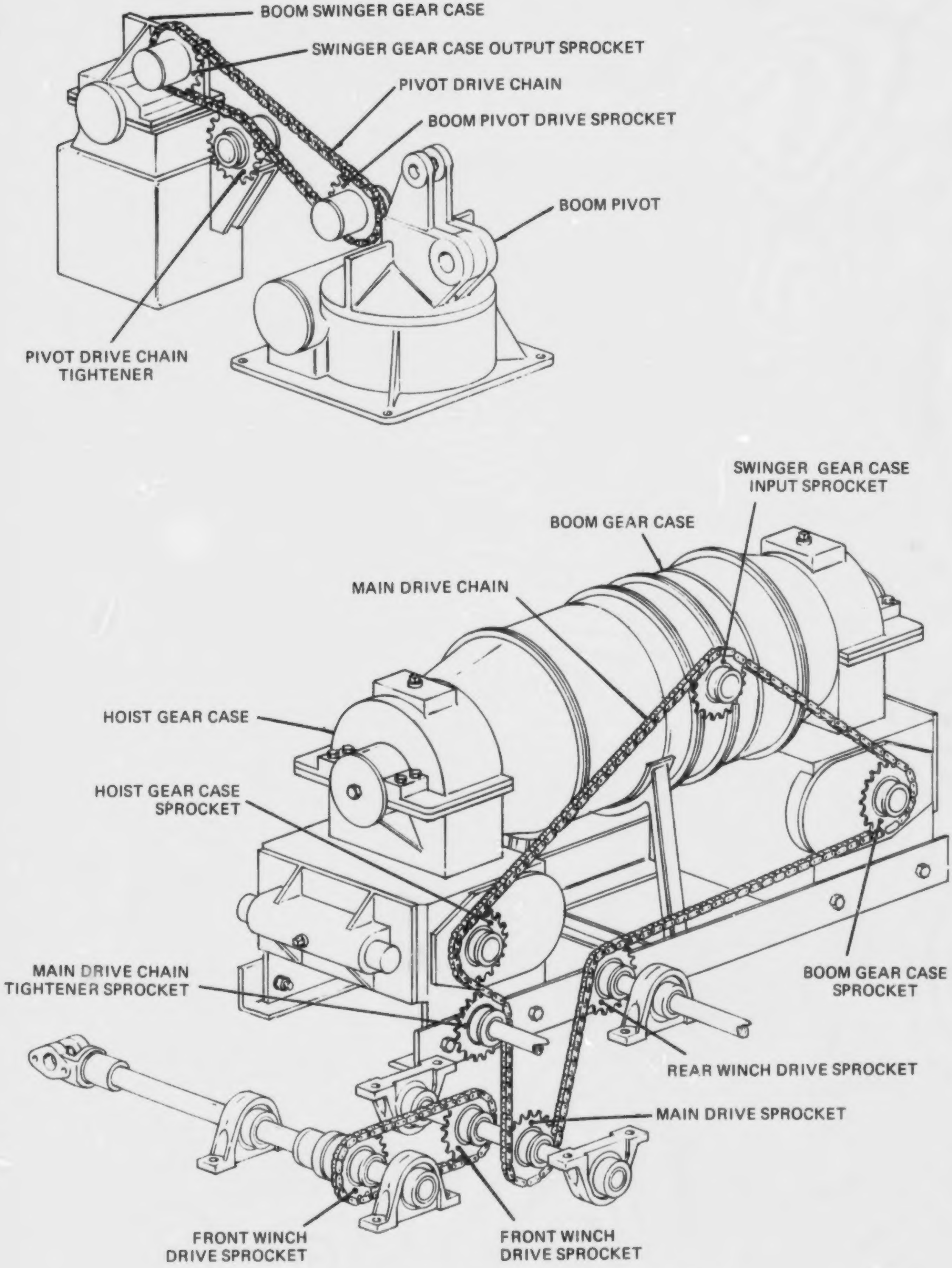

BOOM SWINGER GEAR CASE
SWINGER GEAR CASE OUTPUT SPROCKET
PIVOT DRIVE CHAIN
BOOM PIVOT DRIVE SPROCKET
BOOM PIVOT
PIVOT DRIVE CHAIN TIGHTENER
SWINGER GEAR CASE INPUT SPROCKET
BOOM GEAR CASE
MAIN DRIVE CHAIN
HOIST GEAR CASE
HOIST GEAR CASE SPROCKET
MAIN DRIVE CHAIN TIGHTENER SPROCKET
BOOM GEAR CASE SPROCKET
REAR WINCH DRIVE SPROCKET
MAIN DRIVE SPROCKET
FRONT WINCH DRIVE SPROCKET
FRONT WINCH DRIVE SPROCKET

Figure 36-19. Main Drive Chain and Associated Parts.

TA233907

Section VII. UNDERWATER VENTILATING SYSTEMS

36-24. Purpose.

a. Combat and transport vehicles, if expected to ford deep water or operate in surf landings, must be specially prepared or equipped to go through such an operation and be used immediately. This means that the vehicle must be able to go through fording or landing operations and continue to operate in a normal condition; that is, the special preparations must not reduce the operative effectiveness of the vehicle.

b. Late-type ordnance transport vehicles are specially designed and built for fording and landing operations without modifications. Necessary waterproofing and engine-accessory ventilating systems are already installed on such vehicles. All breathing mechanisms on the vehicles are connected to the carburetor air cleaner and secure air through it. Most important is the engine, which requires large amounts of air for operation. But in addition, the carburetor float chamber, brake master cylinder, fuel tank, transmission and transfer, ignition distributor, and the crankcase ventilator are all vented through the air cleaner. For normal fording operations where a specified depth will not be exceeded (for example, 30 inches on the 1/4-ton 4x4 utility truck M151), no special preparations are required. For deepwater fording, special air intake and exhaust extension tubes must be installed. These raise the height of the intake and exhaust so that deeper water can be forded. All instruments, switches, starter, generator, regulator, battery vents, ignition filter, distributor, and ignition cables are waterproofed, because they will be immersed during fording operations.

c. With tanks and tanklike vehicles, the problems of waterproofing and engine ventilation are different from transport vehicles. With tanks, the hull itself must be made waterproof so the individual engine components do not require special treatment or venting. On this type of vehicle, all normal or abnormal openings (cracks, seams, and holes) must be sealed tightly so that no water can enter when the tank is immersed. Examples of normal openings that must be sealed include filled caps, machinegun mounts, and hull ventilators. These generally are sealed by use of nonhygroscopic tape and sealing compounds. Examples of abnormal openings that must be sealed include holes (missing bolts, etc) and cracks or seams in the hull. These can be sealed by first caulking the larger holes with rags, and then covering all openings with sealing compound. In addition, special gun shield covers are used to prevent entrance of water around the shield. Special air intake and air exhaust stacks (fig. 36-20) must be installed, and sealing boots placed on machinegun ports in the hull.

36-25. Applications.

a. Operation of a transport vehicle under water is made possible by the sealing, at time of manufacture, of all parts or assemblies that are affected immediately by the entrance of water. Watertight housings are provided for such parts as the instruments, switches, starter, generator, regulator, and distributor.

b. A series of ventilating tubes (fig. 36-21) are required to provide venting of various accessories, as described below.

(1) The carburetor float chamber is vented to the air horn by an internal passage and is extended to the air cleaner tube by an external tube (6).

(2) The brake master cylinder is vented through the tube (5) that extends up between the foot pedals to the dash elbow (4), mounted on the dash, and the dash elbow to the dash tee tube (3) to the dash tee (15), and the air cleaner to the dash tee tube (14) to the air cleaner.

(3) The fuel tank is vented through the gasoline tank to the air cleaner vent tube (2) which connects to the air cleaner.

(4) The transmission and transfer are vented through the transfer to the dash tee vent tube (13) connected to the top of the transfer to the air cleaner through the dash tee (15) and the air cleaner to the dash tee tube (14).

(5) Positive circulation of air through the distributor housing is ensured by connecting the distributor to the vacuum line tube (11) and the distributor to the air cleaner tube (12). One tube (11) from the air cleaner provides an air intake for

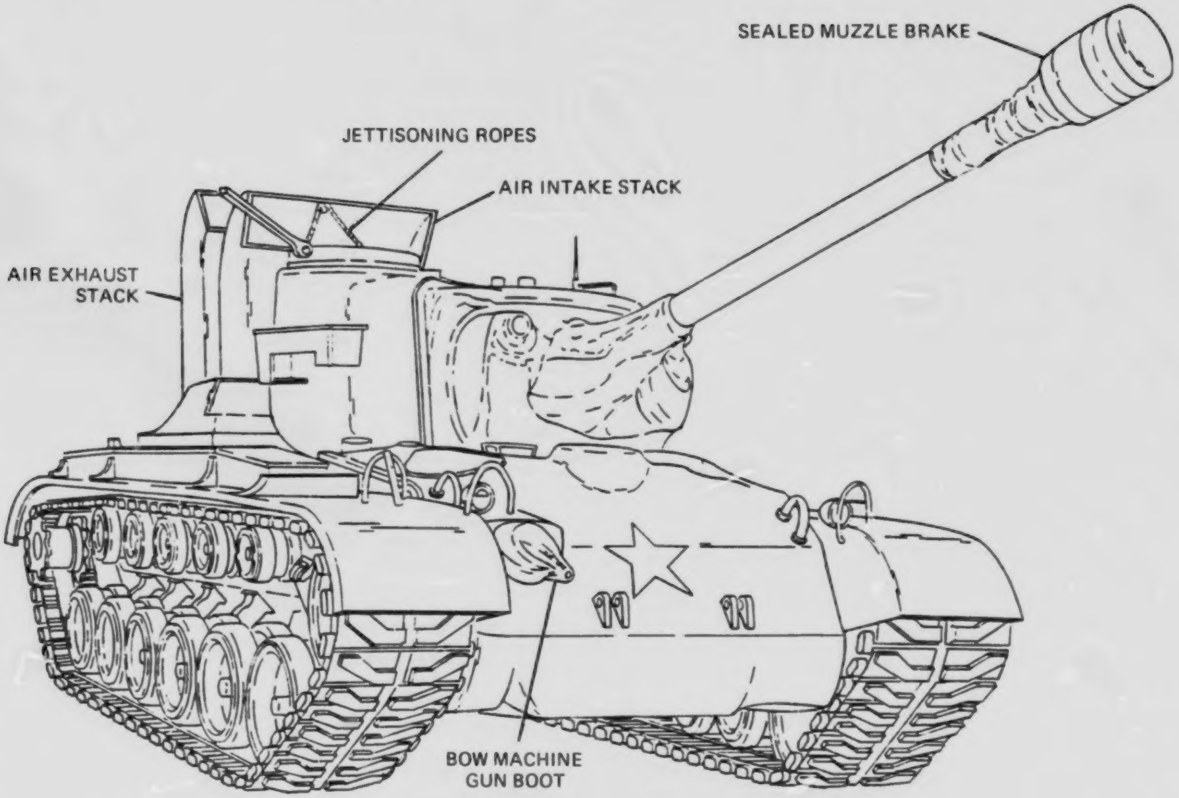


Figure 36-20. Tank Prepared for Deepwater Fording.

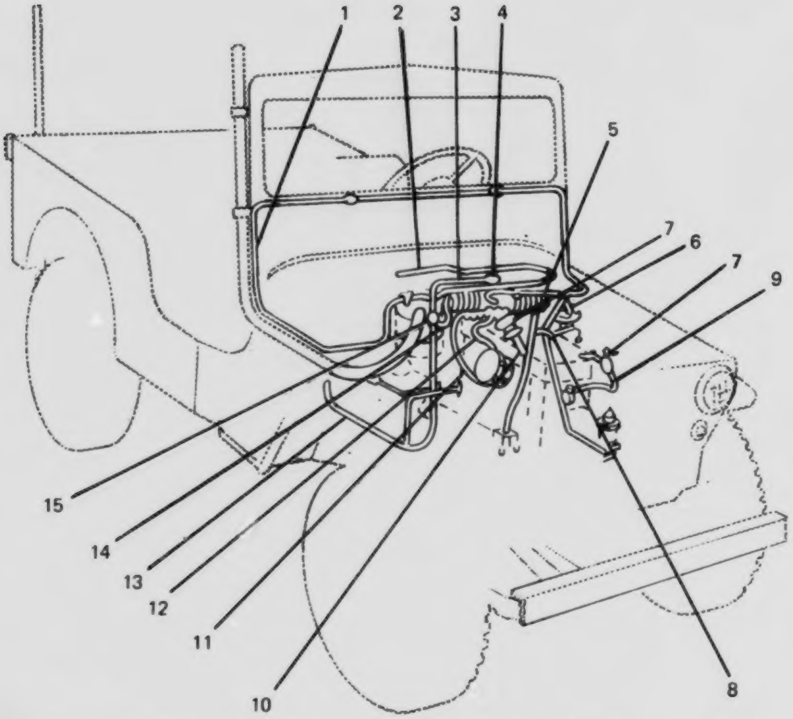
the venting; the other tube (12) is connected to the vacuum line tee (8) in the windshield wiper vacuum line. This vacuum connection provides positive ventilation and will draw off any water that might possibly enter or collect in the distributor. The elbow, used as a connector at the end of the windshield wiper vacuum tube, is connected to the tube leading to the distributor.

(6) The crankcase ventilation system must be shut off during engine immersion. This is accomplished by having a breather shutoff valve (fig. 36-22) in the breather linked to a shutoff knob in the driving compartment. When the valve is closed, a pressure builds up in the engine crankcase that prevents the entrance of water.

c. A special type of air cleaner (fig. 36-23), mounted on the engine side of the dash panel, is used with underwater ventilating systems. The air cleaner functions in the same manner as other air cleaners, but it has a series of connecting tees by means of which the venting lines from the various accessories can be connected. As shown in figures 36-22 and 36-23, lines to the air cleaner are run from the fuel tank, distributor, brake master, and cylinder. In addition, note that the air compressor (for the airbrakes) also draws its air from the air cleaner. The flange to the left on the air cleaner shown in figure 36-23 provides a means of connecting the air intake extension.

d. It is extremely important, in any fording operation, to observe the procedures outlined in the applicable technical manual. These procedures specify the maximum depth of water to be forded by normal and by deepwater fording, the speed at which the vehicle should be driven (3 to 4 mph), and the correct transmission gear ratio (lowor low-low).

TA233908



1 – WINDSHIELD WIPER TO AIR CLEANER VENT TUBE
2 – GASOLINE TANK TO AIR CLEANER VENT TUBE
3 – DASH ELBOW TO DASH TEE TUBE
4 – DASH ELBOW
5 – MASTER CYLINDER TO DASH ELBOW VENT TUBE
6 – CARBURETOR TO AIR CLEANER VENT TUBE
7 – CRANKCASE VENTILATION VALVES
8 – VACUUM LINE TEE
9 – CRANKCASE VENTILATION OUTLET TUBE
10 – CRANKCASE VENTILATION INLET TUBE
11 – DISTRIBUTOR TO VACUUM LINE TUBE
12 – DISTRIBUTOR TO AIR CLEANER TUBE
13 – TRANSFER TO DASH TEE VENT TUBE
14 – AIR CLEANER TO DASH TEE TUBE
15 – DASH TEE

Figure 36-21. Ventilation System for Deepwater Fording.

TA233909

681

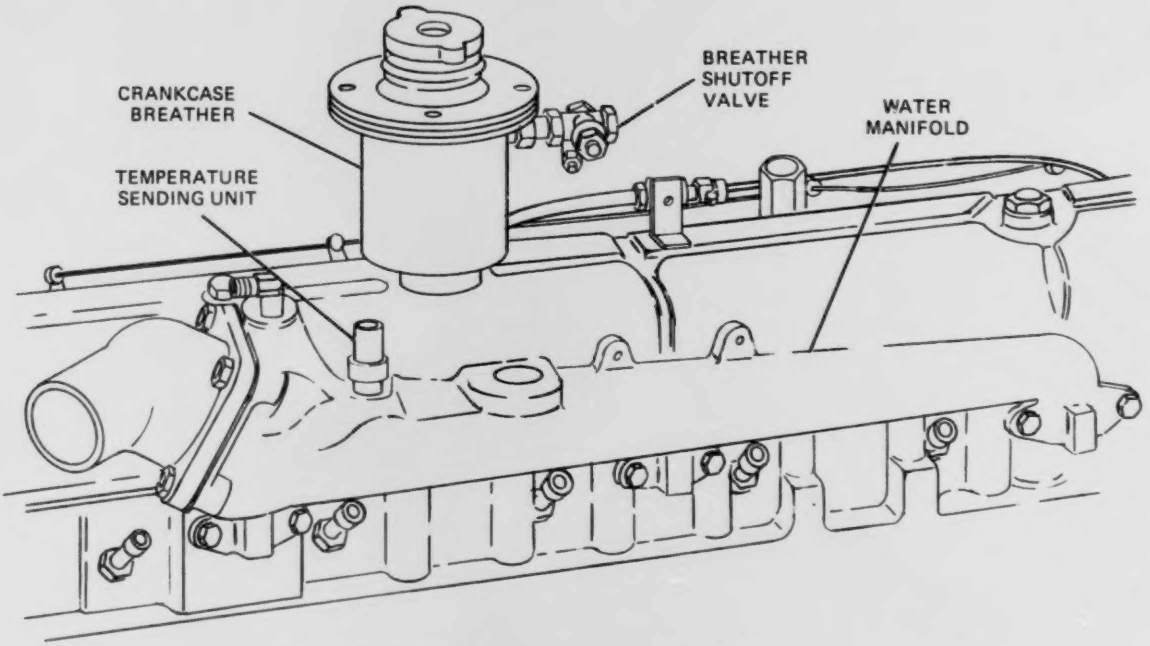

CRANKCASE BREATHER
BREATHER SHUTOFF VALVE
WATER MANIFOLD
TEMPERATURE SENDING UNIT

Figure 36-22. Crankcase Breather for Fording.

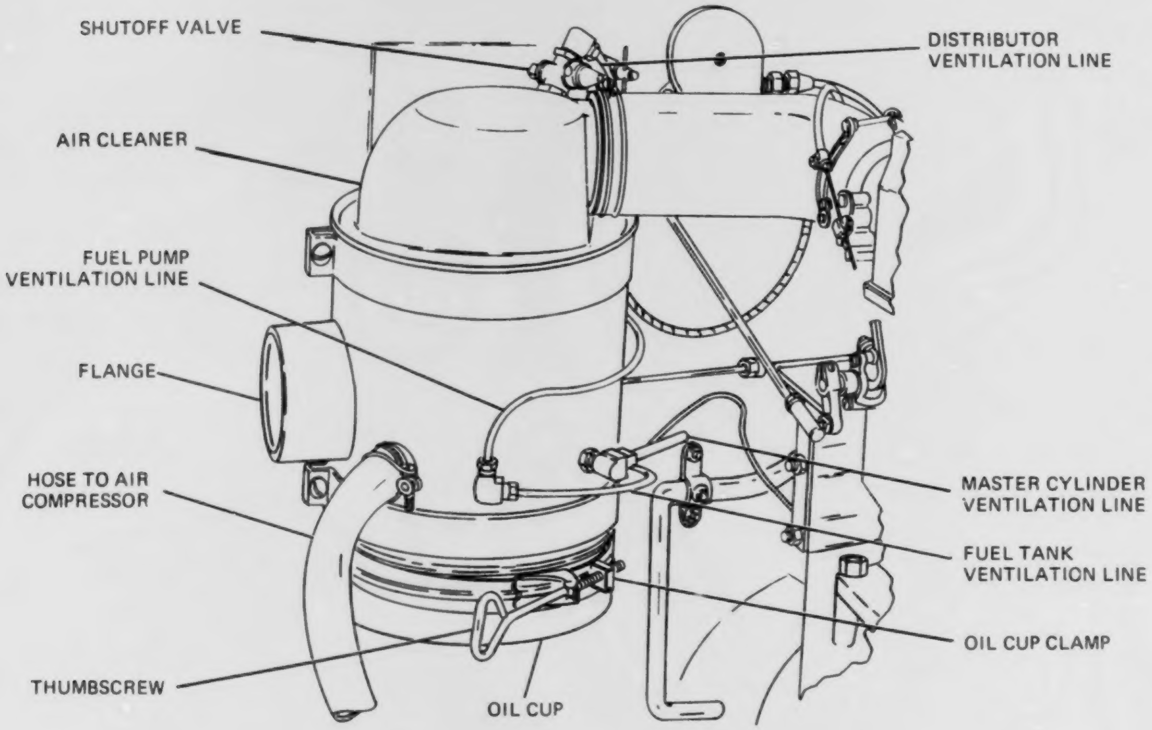

SHUTOFF VALVE
DISTRIBUTOR VENTILATION LINE
AIR CLEANER
FUEL PUMP VENTILATION LINE
FLANGE
HOSE TO AIR COMPRESSOR
MASTER CYLINDER VENTILATION LINE
FUEL TANK VENTILATION LINE
OIL CUP CLAMP
THUMBSCREW
OIL CUP

Figure 36-23. Air Cleaner and Connections for Deepwater Fording. TA233910

682

CHAPTER 37

PRINCIPLES OF REFRIGERATION

Section I. GENERAL

37-1. Ambient Temperature. The temperature of the air surrounding an object is referred to as ambient temperature. As ambient temperature increases, it causes the molecules to interact more violently and increase their length of travel. This results in an increase in physical size. If this principle were applied to a closed system, the result would be an increase in pressure. The opposite happens when the ambient temperature is lowered. The interaction of molecules is less violent and their length of travel is reduced, which results in a decrease in closed system pressure. Figure 37-1 shows the effects of ambient temperature on a closed system.

37-2. Gases Used in Refrigeration. With the exception of changes in state, gases used in refrigeration are recycled much like engine coolant. Different pressures and temperatures cause the gas to change state from liquid to gas and back to a liquid again. The boiling point of the refrigerant changes with system pressure. High pressure raises the boiling point and low pressure reduces it. These gases also provide good heat transfer qualities and do not deteriorate system components. There are two gases used in the refrigeration process: Refrigerant-12 and Refrigerant-22. Extreme caution should be used if they are handled. Refrigerant-12, otherwise known as R-12, Freon-12, or F-12, boils at – 21.7°F (-29.8°C) when at sea level. Because of this low boiling point and its ability to pass through the system endlessly, R-12 is an ideal refrigerant. If the R-12 is pressurized enough, the boiling point would be moved well above the temperatures endured on the hottest day.

Table 37-1 indicates the pressure of Refrigerant-12 at various temperatures. For instance, a drum of Refrigerant at a temperature of 80°F (26.6°C) will have a pressure of 84.1 psi (579.9 kPa). If it is heated to 125°F (51.6°C), the pressure will increase to 167.5 psi (1154.9 kPa). It also can be used conversely to determine the temperature at which Refrigarent-12 boils under various

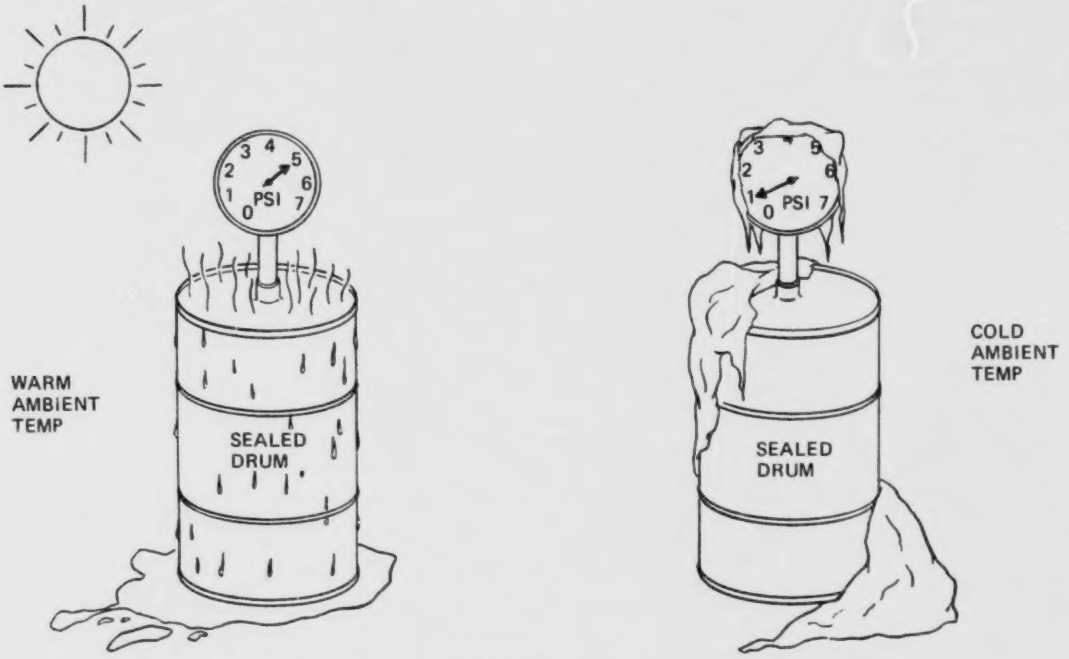


Figure 37-1. Effects of Ambient Temperature on Closed Systems.

TA233911

683

Table 37-1. Refrigerant-12 Pressure-Temperature Relationship.

(°F)	(°C)	(PSIG)	(kPa)	(°F)	(°C)	(PSIG)	(kPa)
-21.7	-29.8C	0 (Atmospheric Pressure)	0(kPa)	55	12.7C	52.0	358.5
				60	15.5C	57.7	397.8
				65	18.3C	63.7	439.2
-20	-28.8C	2.4	16.5	70	21.1C	70.1	482.7
-10	-23.3C	4.5	31.0	75	23.8C	76.9	530.2
-5	-20.5C	6.8	46.9	80	26.6C	84.1	579.9
0	-17.7C	9.2	63.4	85	29.4C	91.7	632.3
5	-15.0C	11.8	81.4	90	32.2C	99.6	686.7
10	-12.2C	14.7	101.4	95	35.0C	108.1	745.3
15	-9.4C	17.7	122.0	100	37.7C	116.9	806.0
20	-6.6C	21.1	145.5	105	40.5C	126.2	870.2
25	-3.8C	24.6	169.6	110	43.3C	136.0	937.7
30	-1.1C	28.5	196.5	115	46.1C	146.5	1010.1
32	0C	30.1	207.5	120	48.8C	157.1	1083.2
35	1.6C	32.6	224.8	125	51.6C	167.5	1154.9
40	4.4C	37.0	255.1	130	54.4C	179.0	1234.2
45	7.2C	41.7	287.5	140	60.0C	204.5	1410.0
50	10.0C	46.7	322.0				

pressures. For example, at a pressure of 30.1 psi (207.5 kPa), Refrigerant-12 boils at 32°F (0°C)

37-3. Refrigeration Cycle. The refrigeration cycle (fig. 37-2) is a continuous closed-loop system. The refrigerant is pumped constantly through the components in the system. By changing the refrigerant pressure, and by removing and adding heat, the refrigeration cycle is completed. The refrigeration cycle operates as follows:

a. The receiver drier collects high-pressure refrigerant in a liquid form. Moisture and impurities also are removed at this point.

b. The refrigerant then is routed to the expansion valve through high-pressure lines and hoses.

c. The expansion valve then reduces refrigerant pressure to the evaporator by allowing a controlled amount of liquid refrigerant to enter it.

d. A stream of air is passed over the coils in the evaporator as refrigerant enters.

e. As the low-pressure refrigerant moves through the coils in the evaporator, it absorbs heat from the airstream, therefore producing a cooling effect.

f. As the refrigerant nears the end of the coils in the evaporator, greater amounts of heat are absorbed. This causes the low-pressure liquid refrigerant to boil and change to a gas as it exits the evaporator.

g. The refrigerant then enters the compressor. The pumping action of the compressor increases refrigerant pressure, which also causes a rise in temperature.

h. The high-pressure, high-temperature gas then enters the condenser, where heat is removed by an outside ambient airstream moving over the coils. This causes the gas to condense and return to a liquid form again.

i. The high-pressure liquid refrigerant now enters the receiver again to begin another cycle. This continuous cycle, along with the dehumidifying and filtering effect, produce a comfortable atmosphere on hot days.

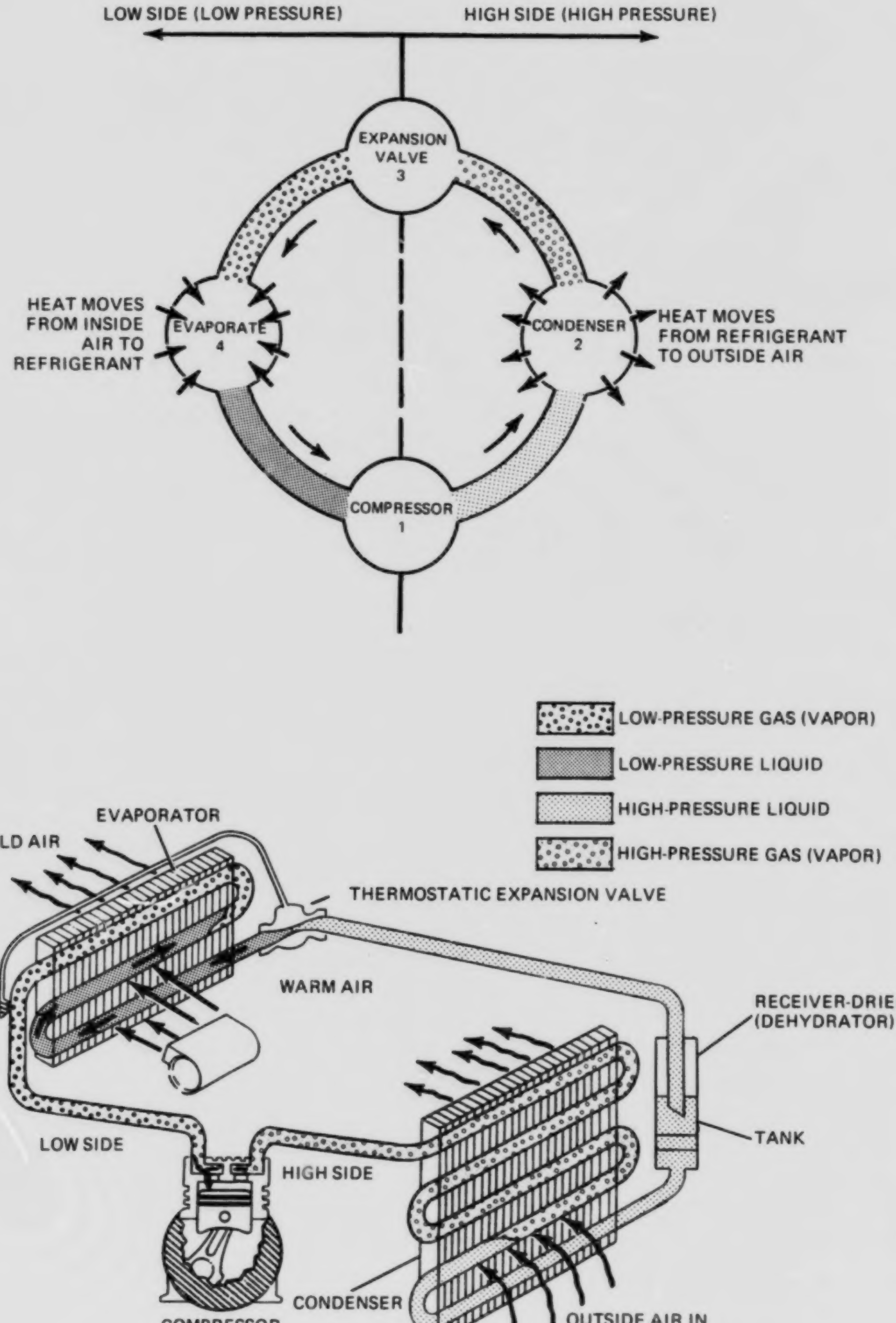

LOW SIDE (LOW PRESSURE)
HIGH SIDE (HIGH PRESSURE)
EXPANSION VALVE 3
HEAT MOVES FROM INSIDE AIR TO REFRIGERANT
EVAPORATE 4
CONDENSER 2
HEAT MOVES FROM REFRIGERANT TO OUTSIDE AIR
COMPRESSOR 1
LOW-PRESSURE GAS (VAPOR)
LOW-PRESSURE LIQUID
HIGH-PRESSURE LIQUID
HIGH-PRESSURE GAS (VAPOR)
EVAPORATOR
COLD AIR
THERMOSTATIC EXPANSION VALVE
WARM AIR
RECEIVER-DRIER (DEHYDRATOR)
TANK
LOW SIDE
HIGH SIDE
CONDENSER
COMPRESSOR
OUTSIDE AIR IN

Figure 37-2. Refrigeration Cycle.

TA233912

Section II. SYSTEM COMPONENTS

37-4. Receiver. The receiver (fig. 37-3), otherwise known as a filter-drier or accumulator-drier, is a cylindrical-shaped metal tank. The tank is hollow with an inlet to the top of the hollow cylinder. The outlet port has a tube attached to it that extends to the bottom of the receiver. This tube assures that only liquid refrigerant will exit the receiver, because any gas entering will tend to float above the liquid.

a. Filter. The filter is mounted inside the receiver on the end of the outlet pipe. This filter removes any impurities from the refrigerant by straining it.

b. Dessicant. A special dessicant or drying agent also is located inside the receiver. This agent removes any moisture from the system.

c. Relief Valve. Some systems utilize a relief valve mounted near the top of the receiver. This valve is designed to open when system pressure exceeds approximately 450 to 500 psi. As the relief valve opens, it vents refrigerant into the atmosphere. As soon as excess pressure is released, the valve closes again so the system will not be evacuated completely.

d. Sight Glass. A sight glass is a small, round, glass-covered hole, sometimes mounted on the outlet side of the receiver near the top. This observation hole is a visual aid used in helping to determine the condition and amount of refrigerant in the system. If bubbles or foam are observed in the sight glass while the system is operating (above 70°F (21°C)), it may indicate the system is low on refrigerant. Some systems have a

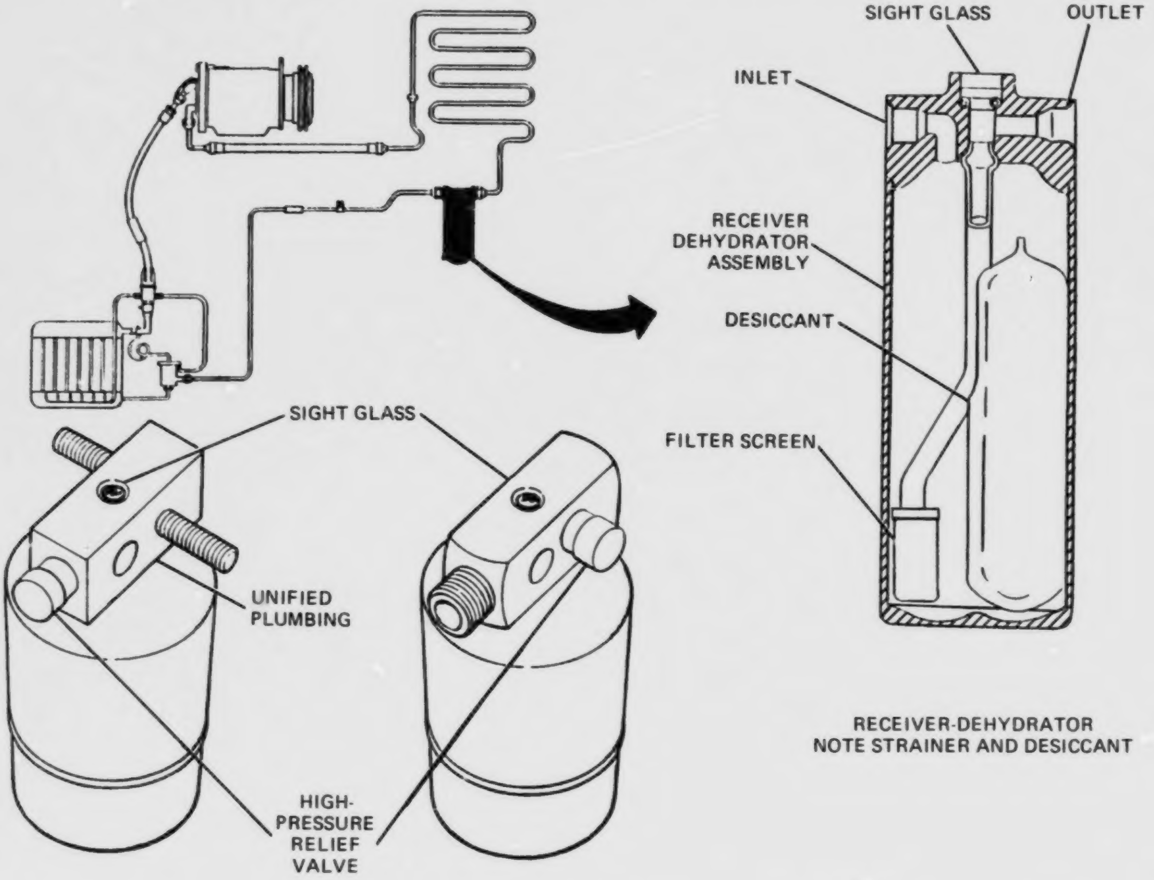

SIGHT GLASS
OUTLET
INLET
RECEIVER DEHYDRATOR ASSEMBLY
DESICCANT
FILTER SCREEN
RECEIVER-DEHYDRATOR
NOTE STRAINER AND DESICCANT
SIGHT GLASS
UNIFIED PLUMBING
HIGH-PRESSURE RELIEF VALVE

Figure 37-3. Receiver and Components.

TA233913

moisture-sensitive element built into the sight glass. If excessive moisture is present, the element turns pink. If the system moisture content is within limits, the element remains blue.

37-5. Refrigerant Expansion Systems. The refrigerant expansion systems are designed to regulate the amount of refrigerant entering the evaporator and also reduce its pressure.

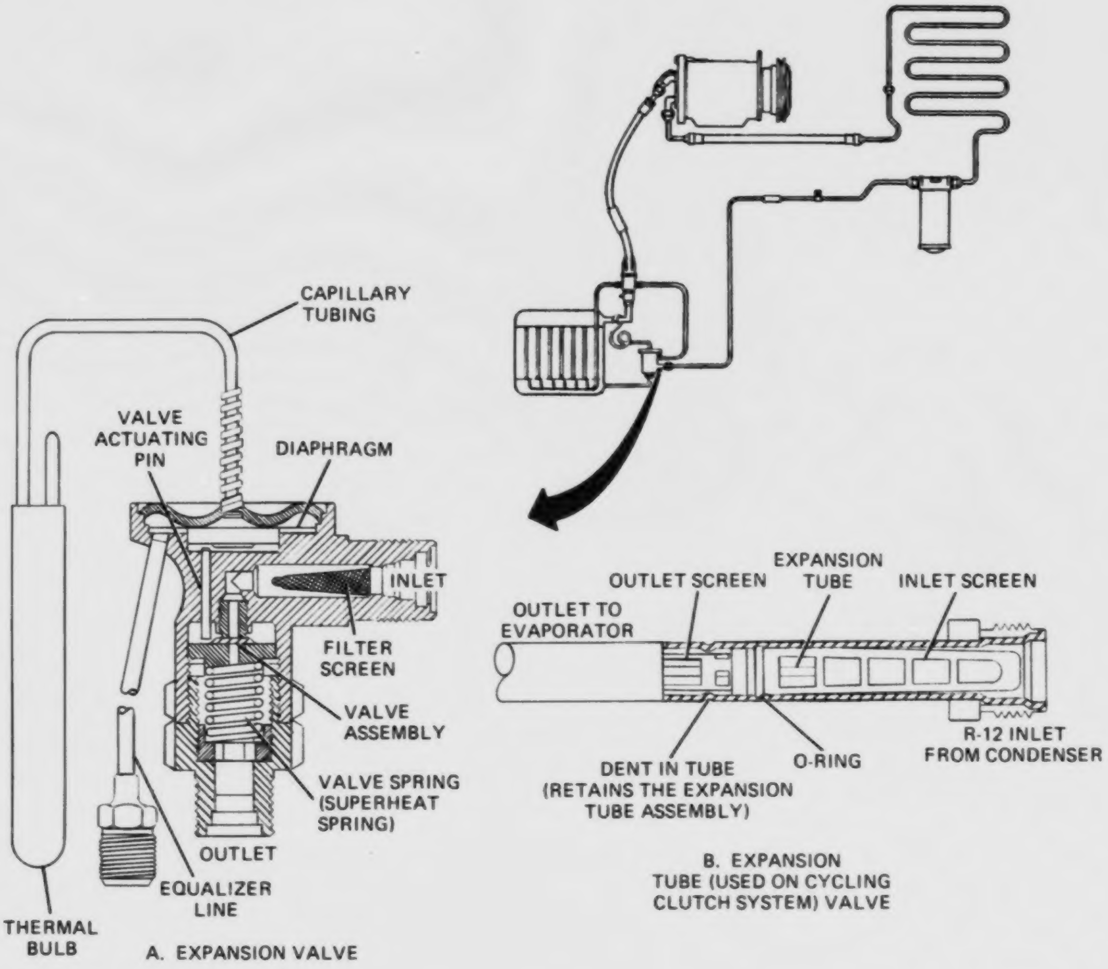
a. *Expansion Valve.* One type of expansion system used on modern vehicles is the expansion valve (A, fig. 37-4). The valve action is controlled by the valve spring, suction manifold, and pressure exerted on the diaphragm from the thermal bulb. Operation of the valve is as follows.

(1) High-pressure liquid refrigerant flows into the valve and is stopped at the needle seat.

(2) If the evaporator is warm, pressure is developed in the thermal bulb and transferred to the diaphragm through the capillary tube.

(3) The diaphragm overcomes the pressure developed in the equalizer tube and valve spring pressure, causing it to move downward.

(4) This movement forces the valve actuating pin downward to open the valve.


CAPILLARY TUBING
VALVE ACTUATING PIN
DIAPHRAGM
INLET
FILTER SCREEN
VALVE ASSEMBLY
VALVE SPRING (SUPERHEAT SPRING)
OUTLET
EQUALIZER LINE
THERMAL BULB
EXPANSION TUBE
OUTLET SCREEN
INLET SCREEN
OUTLET TO EVAPORATOR
R-12 INLET FROM CONDENSER
O-RING
DENT IN TUBE (RETAINS THE EXPANSION TUBE ASSEMBLY)

A. EXPANSION VALVE

B. EXPANSION TUBE (USED ON CYCLING CLUTCH SYSTEM) VALVE

Figure 37-4. Expansion Valve and Expansion Tube.

TA233914

687

As the refrigerant flows, it cools the evaporator and therefore reduces pressure in the thermal bulb. This allows the valve to close and stop refrigerant from flowing into the evaporator. By carefully metering the amount of refrigerant with the expansion valve, the evaporator cooling efficiency is increased greatly.

b. Expansion Tube. The expansion tube (B, fig. 37-4) provides the same functions as the expansion valve. A calibrated orifice is built into the expansion tube. The tube retards the refrigerant flow through the orifice to provide the metered amount of refrigerant to the evaporator. The tube also has a fine screen built in for additional filtration.

37-6. Evaporator. The evaporator is designed to absorb heat from the airstream directed into the driver's compartment. It is a continuous tube looped back and forth through many cooling fins firmly attached to the tube. The evaporator dehumidifies the air by passing an airstream over the cool fins. As this happens, the moisture condenses on the fins and drips down to collect and exit under the vehicle. Dust and dirt also are collected on the moist fins and drain with the moisture. The temperature of the evaporator must be kept above 32°F. Should the temperature fall below 32°F, moisture condensing on the evaporator would freeze, preventing air from passing through the fins. A typical evaporator is shown in figure 37-5. There basically are three methods of regulating evaporator temperature; each is discussed below.

a. Thermostatic Switch. This system (fig. 37-6) uses an electrically operated switch to

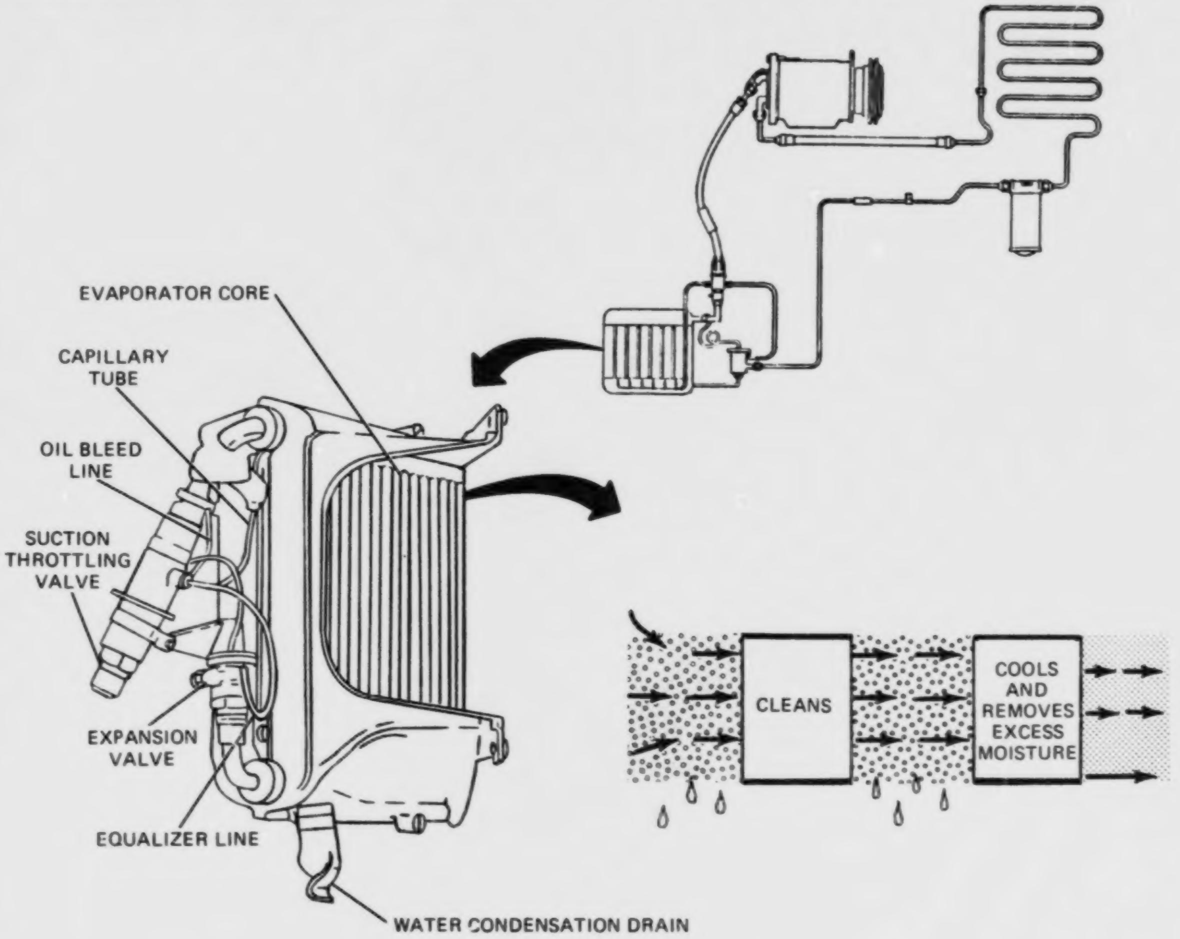


Figure 37-5. Typical Evaporator.

TA233915

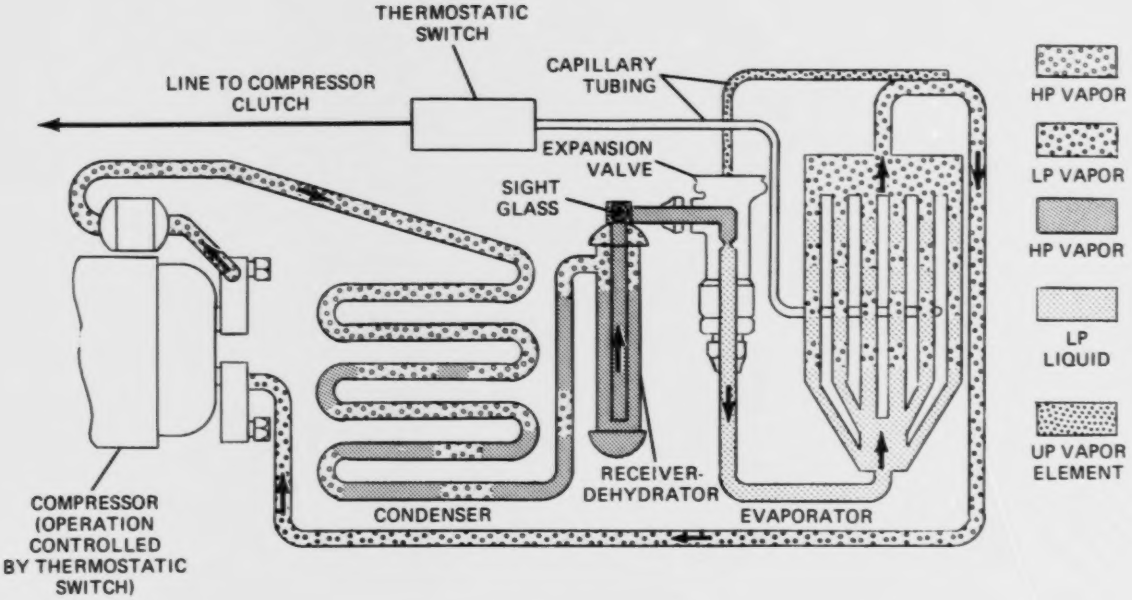

THERMOSTATIC SWITCH
LINE TO COMPRESSOR CLUTCH
CAPILLARY TUBING
EXPANSION VALVE
SIGHT GLASS
RECEIVER-DEHYDRATOR
CONDENSER
EVAPORATOR
COMPRESSOR (OPERATION CONTROLLED BY THERMOSTATIC SWITCH)
HP VAPOR
LP VAPOR
HP VAPOR
LP LIQUID
UP VAPOR ELEMENT

Figure 37-6. Thermostatic Switch.

engage and disengage the compressor. The switch is operated by a sensing bulb placed in the airstream after the evaporator. As the evaporator temperature falls, the thermostatic switch opens to disengage the magnetic clutch in the compressor. When the coil temperature reaches the proper level, the switch again closes to engage the clutch and again drive the compressor.

b. Hot Gas Bypass Valve. The hot gas bypass valve was used on some older models to control evaporator icing (fig. 37-7). The valve is mounted on the outlet side of the evaporator. The high-pressure gas from the compressor joins with the low-pressure gas exiting the evaporator. These two gases mix, causing a pressure increase. The boiling point also increases, resulting in a loss of cooling efficiency. This, in turn, causes the evaporator temperature to increase, thus eliminating freezeup. The compressor is designed to run constantly (when it is activated) in the hot gas bypass valve system.

c. Suction Throttling Valve. The suction throttling valve (fig. 37-8) is used now in place of the hot gas bypass valve system. It is placed in line with the outlet of the evaporator. This system is designed to limit the amount of low-pressure vapor entering the compressor. The suction throttling valve operates as follows:

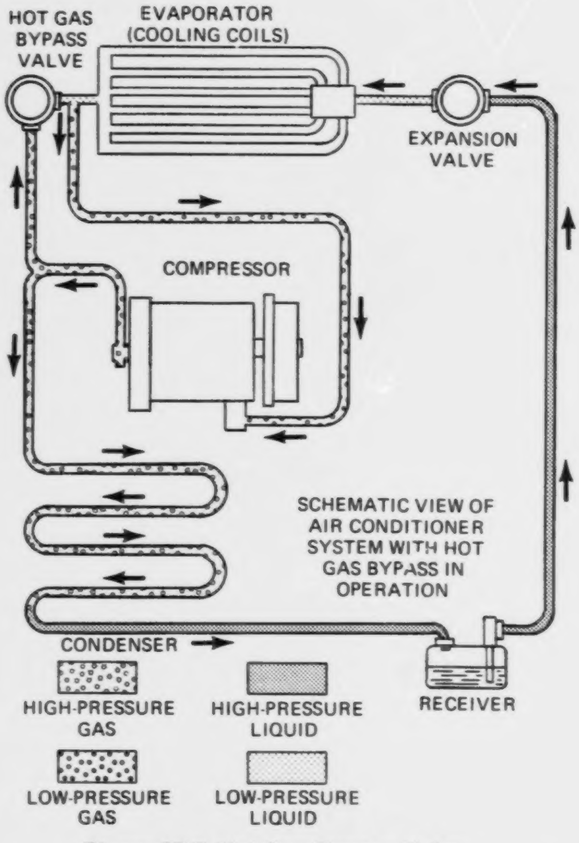
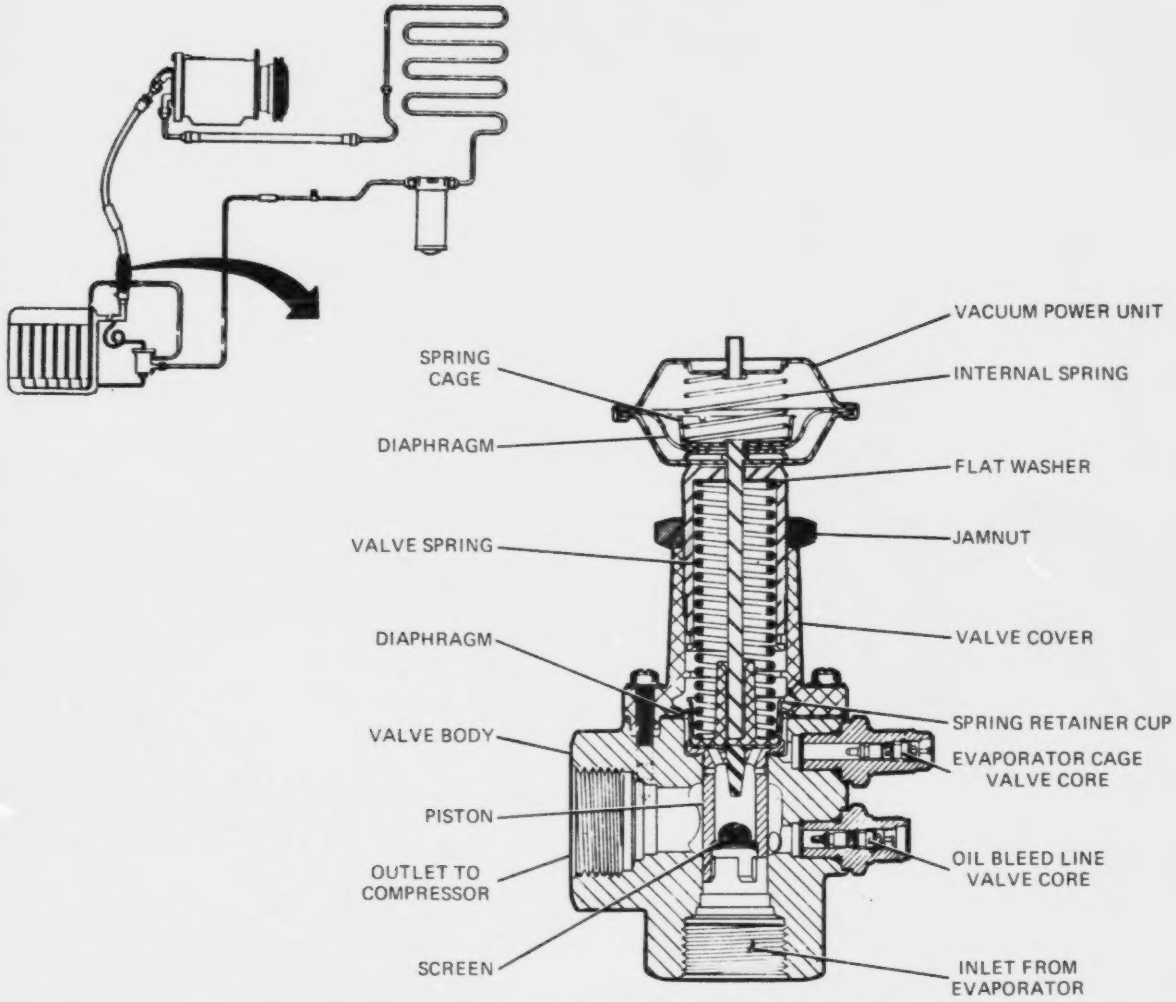

HOT GAS BYPASS VALVE
EVAPORATOR (COOLING COILS)
EXPANSION VALVE
COMPRESSOR
SCHEMATIC VIEW OF AIR CONDITIONER SYSTEM WITH HOT GAS BYPASS IN OPERATION
CONDENSER
RECEIVER
HIGH-PRESSURE GAS
HIGH-PRESSURE LIQUID
LOW-PRESSURE GAS
LOW-PRESSURE LIQUID

Figure 37-7. Hot Gas Bypass Valve.

TA233916

689


VACUUM POWER UNIT
SPRING CAGE
INTERNAL SPRING
DIAPHRAGM
FLAT WASHER
VALVE SPRING
JAMNUT
DIAPHRAGM
VALVE COVER
SPRING RETAINER CUP
VALVE BODY
EVAPORATOR CAGE VALVE CORE
PISTON
OIL BLEED LINE VALVE CORE
OUTLET TO COMPRESSOR
SCREEN
INLET FROM EVAPORATOR

TYPICAL SUCTION THROTTLING VALVE (STV)

Figure 37-8. Suction Throttling Valve.

(1) The outlet pressure enters the valve on the bottom.

(2) The gas pressure passes through a fine screen and small bleeder holes to act on a diaphragm.

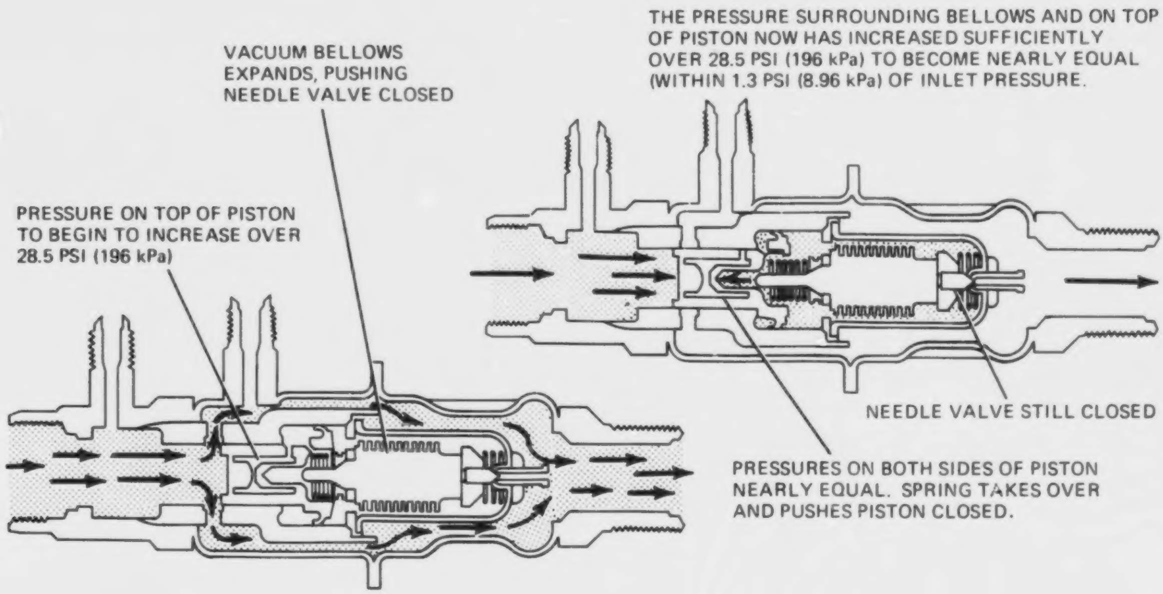
(3) The valve spring and atmospheric pressure oppose the gas pressure on the opposite side of the diaphragm.

(4) As the outlet pressure of the evaporator overcomes the opposing forces, the diaphragm and piston move upward, allowing low-pressure gas to flow through the valve and flow to the inlet of the compressor.

As pressure again drops on the inlet side of the valve, atmospheric pressure and valve spring pressure close the valve again. A vacuum power unit is mounted to the top of the valve that helps reduce valve spring pressure, preventing icing at high elevations.

d. Pilot-Operated Absolute Suction Throttling Valve. The Pilot-Operated Absolute (POA) valve (fig. 37-9) is able to maintain the proper minimum evaporator pressure regardless of

TA233917



VACUUM BELLOWS EXPANDS, PUSHING NEEDLE VALVE CLOSED

PRESSURE ON TOP OF PISTON TO BEGIN TO INCREASE OVER 28.5 PSI (196 kPa)

THE PRESSURE SURROUNDING BELLOWS AND ON TOP OF PISTON NOW HAS INCREASED SUFFICIENTLY OVER 28.5 PSI (196 kPa) TO BECOME NEARLY EQUAL (WITHIN 1.3 PSI (8.96 kPa) OF INLET PRESSURE.

NEEDLE VALVE STILL CLOSED

PRESSURES ON BOTH SIDES OF PISTON NEARLY EQUAL. SPRING TAKES OVER AND PUSHES PISTON CLOSED.

POA VALVE OPEN. OUTLET PRESSURE AROUND BELLOWS HAS REDUCED TO 28.5 PSI (196 kPa), CAUSING BELLOWS TO EXPAND AND CLOSE NEEDLE VALVE.

POA VALVE CLOSED. INCREASE IN PRESSURE ON TOP OF PISTON HAS PERMITTED SPRING TO CLOSE PISTON. PRESSURE IN BELLOWS AREA IS STILL NOT HIGH ENOUGH TO CONTRACT BELLOWS AND OPEN VALVE.

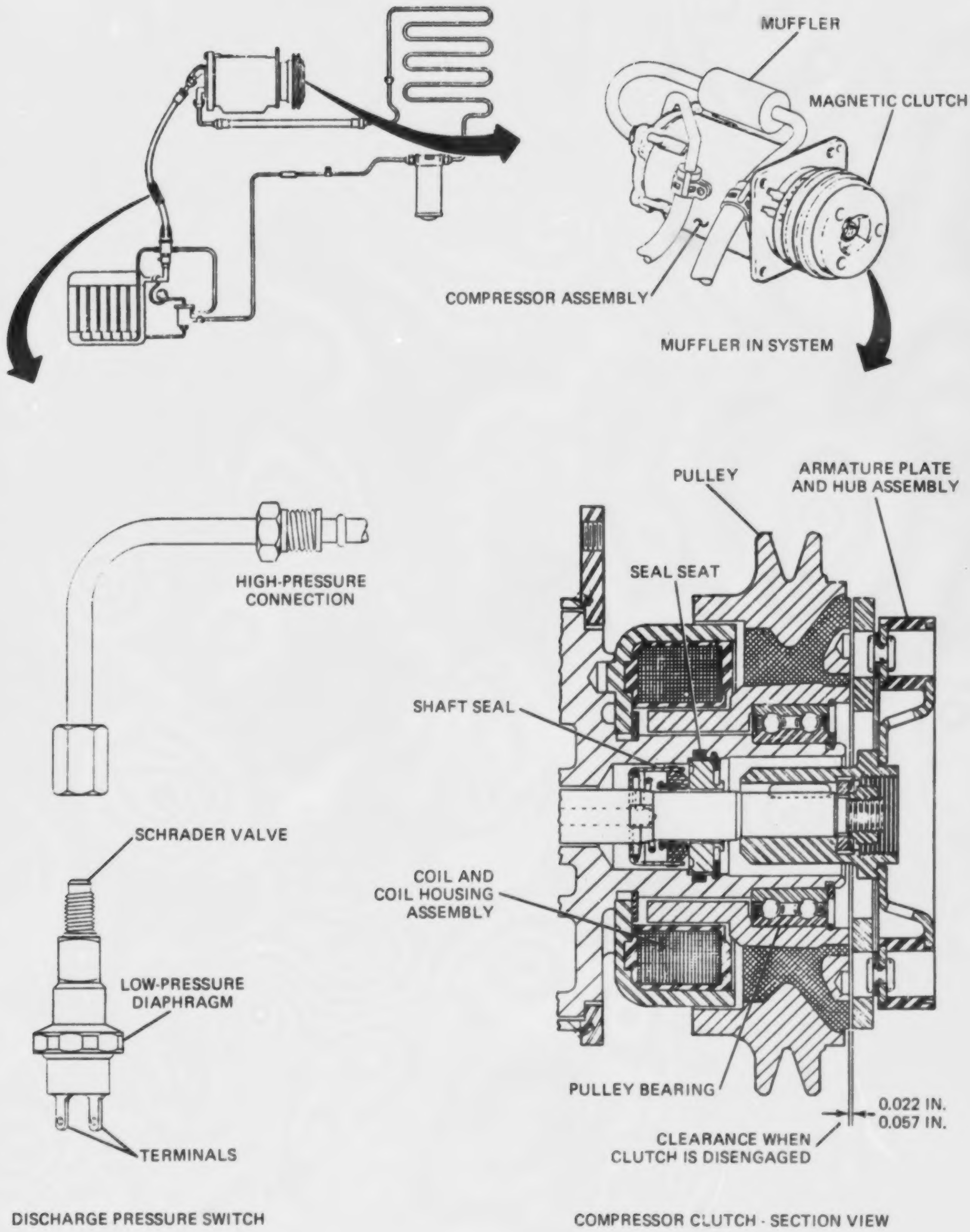
Figure 37-9. Pilot-Operated Absolute (POA) Valve.

compressor speed, evaporator temperature, and changes in altitude. The POA valve is operated by a bellows containing an almost perfect vacuum. The expanding and contracting action of the bellows operates a needle valve, regulating its surrounding pressure. As inlet and outlet pressure are equalized, spring pressure closes the valve. The pressure differential across the valve then forces the piston toward the lower pressure, therefore opening the valve to allow refrigerant to flow.

37-7. Compressor. The compressor is designed to increase the pressure of vaporized refrigerant exiting the evaporator. When the system is activated, a coil produces a magnetic field that engages the drive pulley to operate the compressor (fig. 37-10). Some compressors are protected from overheating by a superheat switch located inside the compressor (fig. 37-11). Should the compressor develop an excess amount of heat due to a loss of refrigerant or oil, the superheat switch disengages the compressor by completing a circuit and opening a thermal fuse. A compressor discharge pressure switch sometimes is used to protect against a low refrigerant condition (fig. 37-10). This switch disengages the compressor drive to protect the system when discharge pressure drops below approximately 35 psi (241 kPa). A muffler often is used on the outlet side of the compressor (fig. 37-10). The muffler helps reduce compressor pumping noise and line vibrations.

a. Two-Cylinder Axial. The two-cylinder axial compressor (fig. 37-12) has two reciprocating pistons fitted into cylinders. A special valve plate, operated by differential pressures, is used to control gas flow.

b. Four-Cylinder Radial. The four-cylinder radial compressor (fig. 37-13) positions four pistons at right angles to each other. The pistons are driven by a central shaft connected to the engine by the electric clutch assembly and V-belt. The radial compressor's compact design is very popular on today's vehicles.


MUFFLER
MAGNETIC CLUTCH
COMPRESSOR ASSEMBLY
MUFFLER IN SYSTEM
HIGH-PRESSURE CONNECTION
SCHRADER VALVE
LOW-PRESSURE DIAPHRAGM
TERMINALS
PULLEY
ARMATURE PLATE AND HUB ASSEMBLY
SEAL SEAT
SHAFT SEAL
COIL AND COIL HOUSING ASSEMBLY
PULLEY BEARING
0.022 IN.
0.057 IN.
CLEARANCE WHEN CLUTCH IS DISENGAGED

DISCHARGE PRESSURE SWITCH

COMPRESSOR CLUTCH - SECTION VIEW

Figure 37-10. Compressor Components.

TA233919

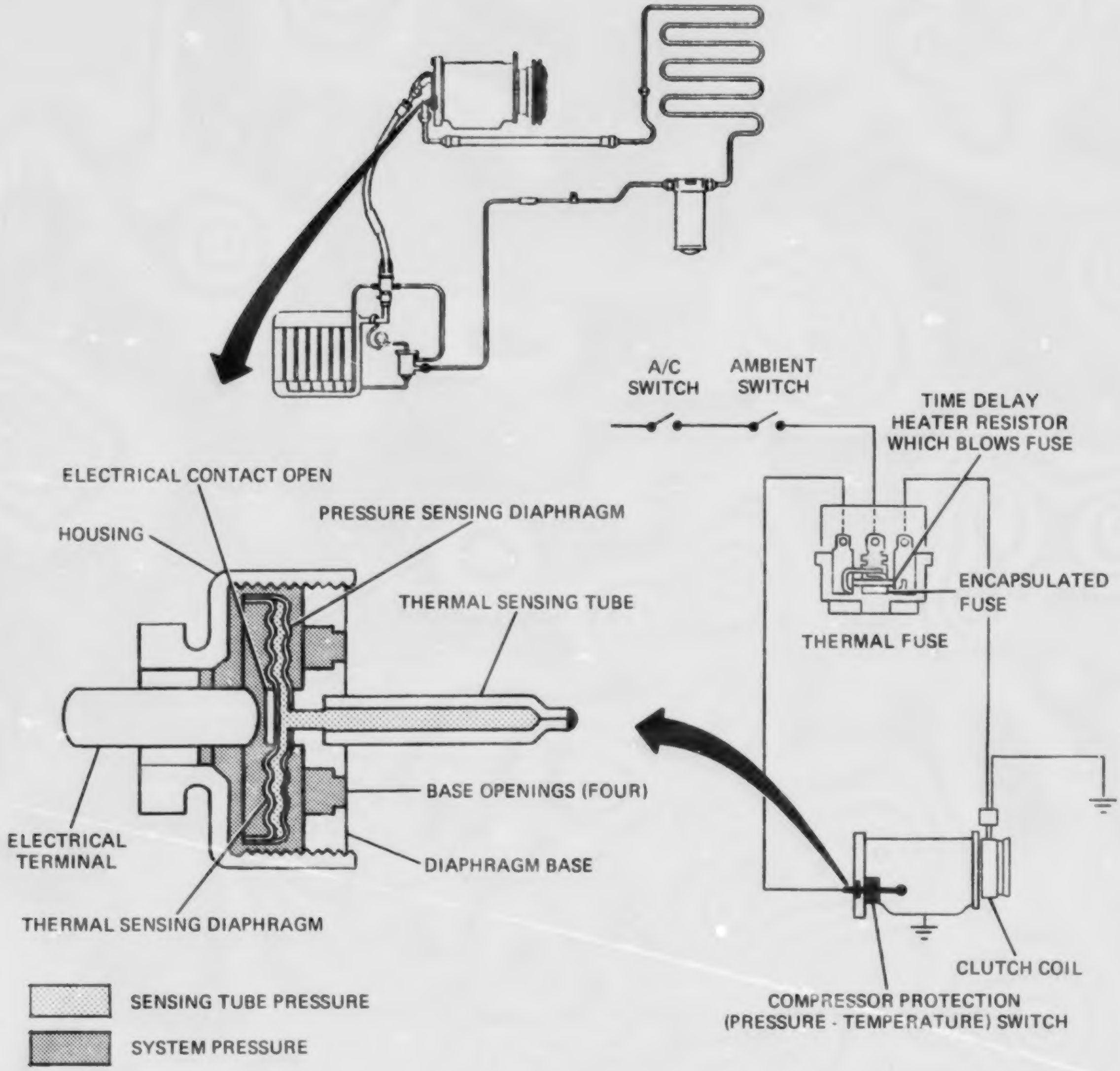

A/C SWITCH
AMBIENT SWITCH
TIME DELAY HEATER RESISTOR WHICH BLOWS FUSE
ELECTRICAL CONTACT OPEN
PRESSURE SENSING DIAPHRAGM
HOUSING
THERMAL SENSING TUBE
ENCAPSULATED FUSE
THERMAL FUSE
BASE OPENINGS (FOUR)
ELECTRICAL TERMINAL
DIAPHRAGM BASE
THERMAL SENSING DIAPHRAGM
CLUTCH COIL
COMPRESSOR PROTECTION (PRESSURE - TEMPERATURE) SWITCH
SENSING TUBE PRESSURE
SYSTEM PRESSURE

Figure 37-11. Compressor Superheat Switch.

TA233920

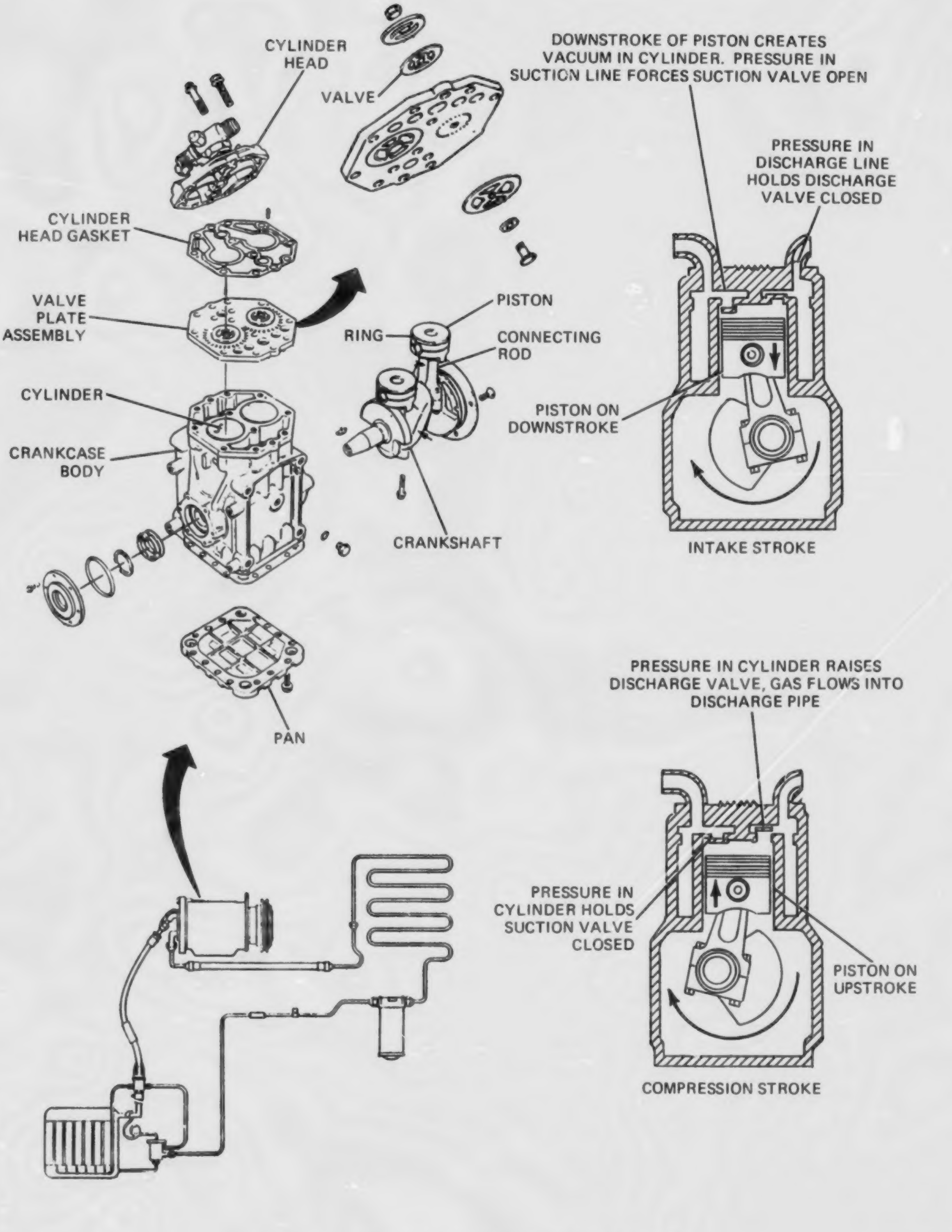

CYLINDER HEAD
VALVE
CYLINDER HEAD GASKET
VALVE PLATE ASSEMBLY
PISTON
RING
CONNECTING ROD
CYLINDER
CRANKCASE BODY
CRANKSHAFT
PAN
DOWNSTROKE OF PISTON CREATES VACUUM IN CYLINDER. PRESSURE IN SUCTION LINE FORCES SUCTION VALVE OPEN
PRESSURE IN DISCHARGE LINE HOLDS DISCHARGE VALVE CLOSED
PISTON ON DOWNSTROKE
INTAKE STROKE
PRESSURE IN CYLINDER RAISES DISCHARGE VALVE, GAS FLOWS INTO DISCHARGE PIPE
PRESSURE IN CYLINDER HOLDS SUCTION VALVE CLOSED
PISTON ON UPSTROKE
COMPRESSION STROKE

Figure 37-12. Two-Cylinder Axial Compressor.

TA233921

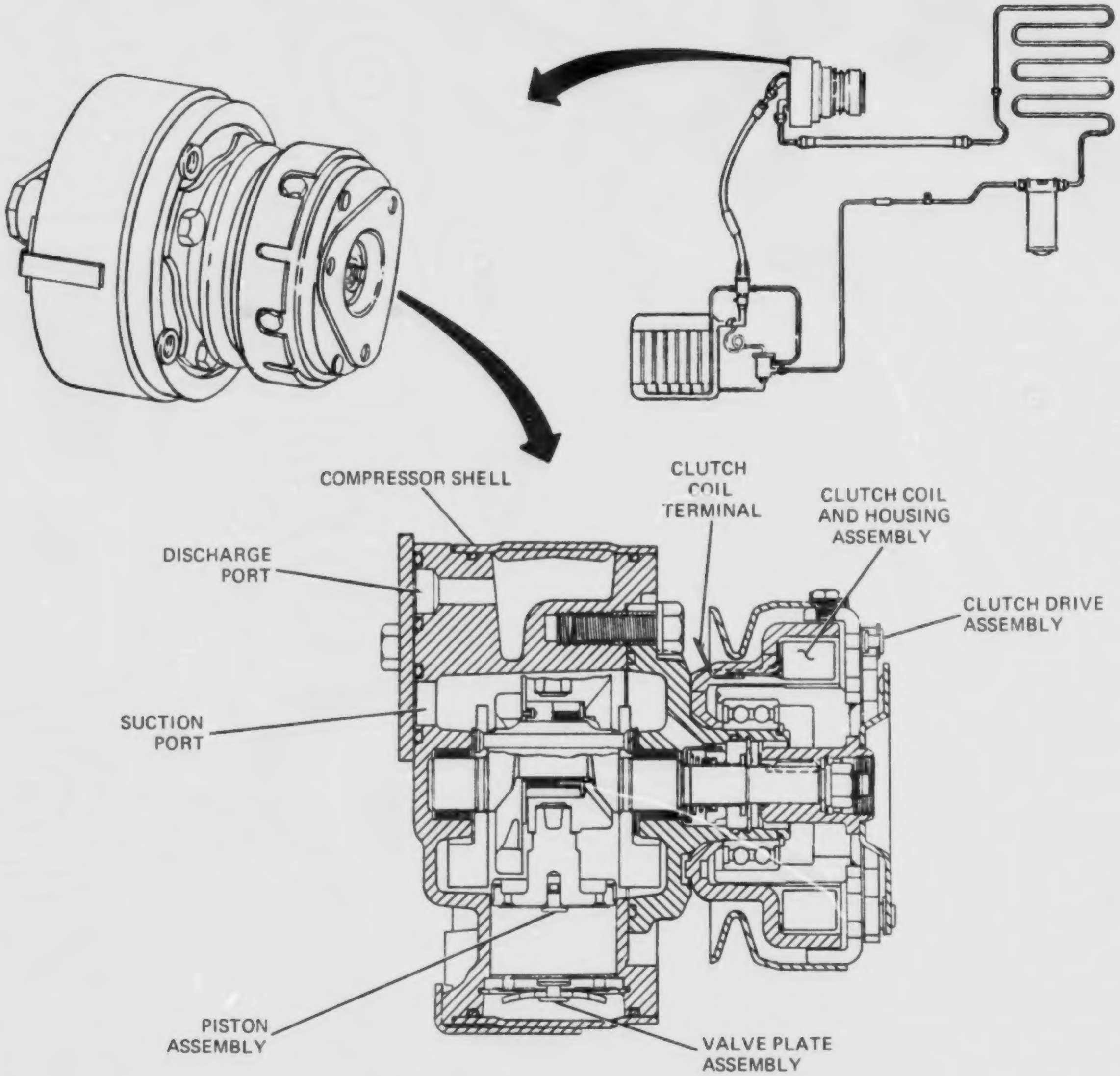

COMPRESSOR SHELL
CLUTCH COIL TERMINAL
CLUTCH COIL AND HOUSING ASSEMBLY
DISCHARGE PORT
CLUTCH DRIVE ASSEMBLY
SUCTION PORT
PISTON ASSEMBLY
VALVE PLATE ASSEMBLY

Figure 37-13. Four-Cylinder Radial Compressor.

TA233922

c. Six-Cylinder Axial Compressor. This design uses three double-ended pistons driven by a wobble plate (fig. 37-14). The three cylinders effectively produce a six-cylinder compressor. As the shaft rotates, the wobble plate displaces the pistons perpendicular to the shaft. Piston drive balls are used to cut down friction between the wobble plate and pistons. Piston rings also are used to aid in sealing.

37-8. Condenser. The condenser (fig. 37-15) is designed to remove heat from the compressed refrigerant, returning it to a liquid state. Condensers generally are made from a continuous tube looped back and forth through rigidly mounted cooling fins. They are made of aluminum and can encounter pressures of approximately 150 to 300 psig, and temperatures ranging from 120° to 200°F (48° to 93°C). The condenser usually is mounted in front of the radiator and subjected to a steady stream of cooling air.

37-9. Refrigeration Oil. Refrigeration oil provides lubrication for the compressor. Each system has a certain amount of refrigeration oil (usually approximately 6 to 10 oz (177 to 296 mL)) added to the system initially. If the system stays sealed, the oil will not break down or need to be changed. Refrigeration oil is highly refined and must be free of moisture.

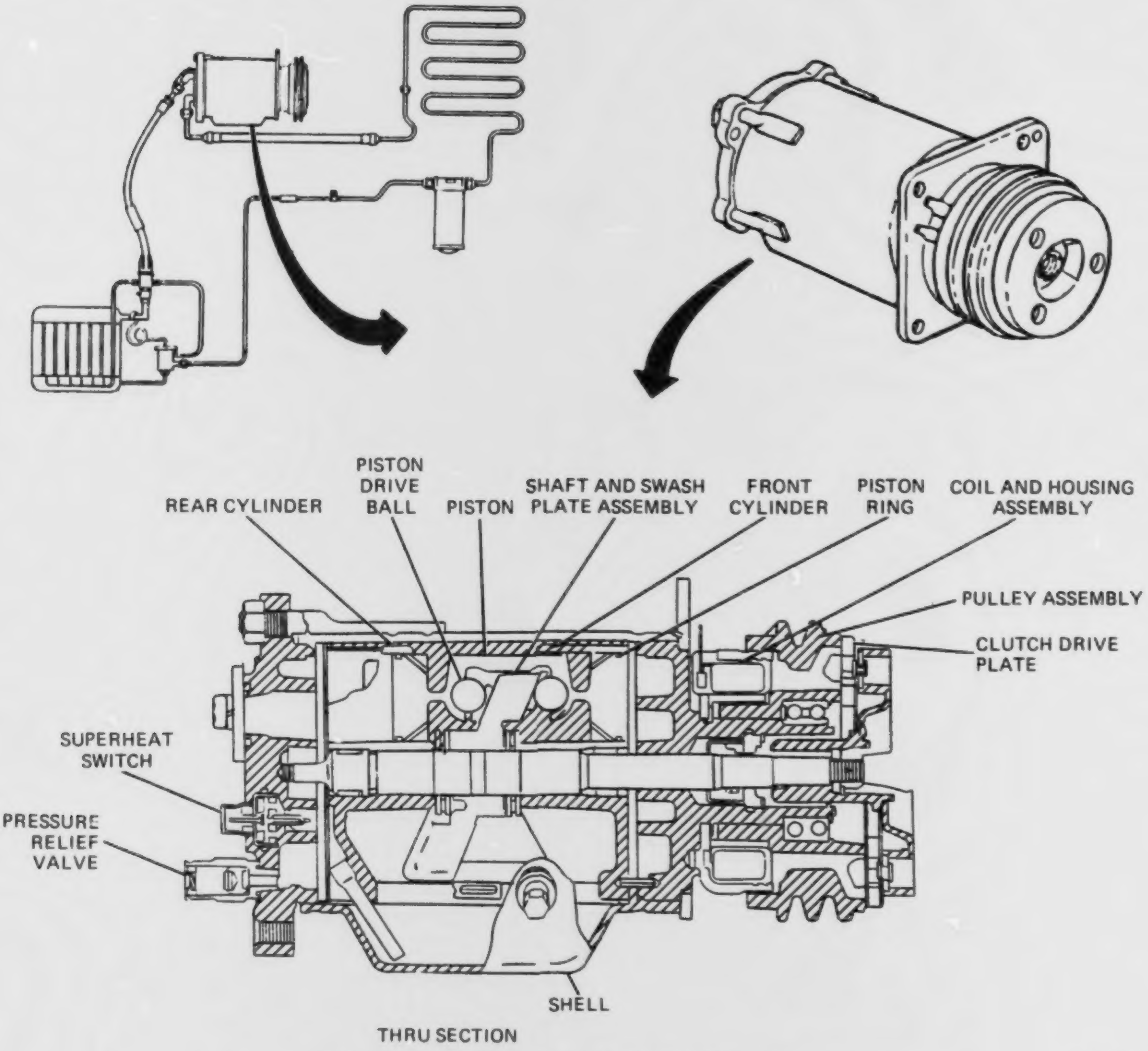
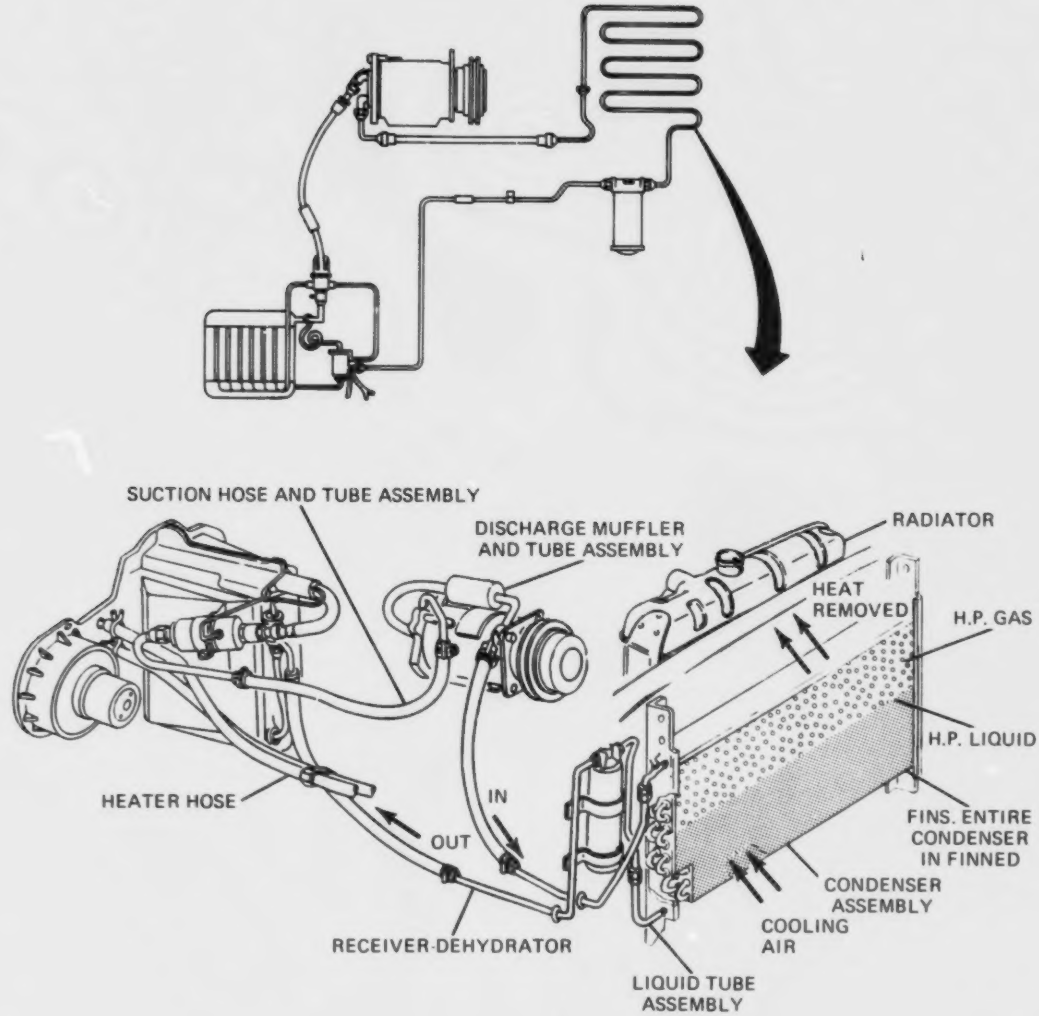

PISTON DRIVE BALL
REAR CYLINDER
PISTON
SHAFT AND SWASH PLATE ASSEMBLY
FRONT CYLINDER
PISTON RING
COIL AND HOUSING ASSEMBLY
PULLEY ASSEMBLY
CLUTCH DRIVE PLATE
SUPERHEAT SWITCH
PRESSURE RELIEF VALVE
SHELL
THRU SECTION

Figure 37-14. Six-Cylinder Axial Compressor.

TA233923


SUCTION HOSE AND TUBE ASSEMBLY
DISCHARGE MUFFLER AND TUBE ASSEMBLY
RADIATOR
HEAT REMOVED
H.P. GAS
H.P. LIQUID
FINS. ENTIRE CONDENSER IN FINNED
CONDENSER ASSEMBLY
COOLING AIR
LIQUID TUBE ASSEMBLY
RECEIVER-DEHYDRATOR
HEATER HOSE
IN
OUT

TYPICAL CONDENSER.
UNIT MOUNTS IN FRONT OF RADIATOR.

Figure 37-15. Condenser.

TA233924

CHAPTER 38

TRAILERS AND SEMITRAILERS

Section I. SEMITRAILERS

38-1. General Description. A typical semitrailer chassis (fig. 38-1) consists mainly of a frame, spring suspension, axle, fifth-wheel connection, and a landing gear. It resembles the conventional truck chassis in that its frame is made of two pressed-steel side members with several crossmembers and has laminated leaf spring suspension. The wheels and tires are interchangeable with those of the tractor used for hauling the trailer. Figure 38-1 illustrates a semitrailer chassis with tandem axles for carrying heavy trailer loads.

Early semitrailer frames were built of straight side members, which meant that the rear of a level trailer body had to be at a considerable height above the ground to clear the rear wheels of the tractor. Such a high frame is not acceptable because it heightens the center of gravity, making it easier to overturn the trailer. A kickup (fig. 38-1) in the semitrailer frame permits a lower center of gravity without reducing the necessary clearance space above the rear wheels of the motor vehicle.

Crossmembers are located where the greatest strains occur to the trailer frame. They may be tubular, channel, or box-shaped, with gusset plates riveted or welded to the side members to make a rigid, strong frame.

Another type of semitrailer with a variable wheelbase is the pole trailer used for transporting long or irregularly shaped goods, such as poles, pipes, or structural members. In this case, the pole, or boom, forms the trailer frame. The pole is attached to a turntable mounted on the tractor in much the same manner as a fifth wheel. The trailer axle unit is attached by adjustable clamps to the other end of the pole.

A truck tractor used to haul a semitrailer must be a special design. Its wheelbase is shorter than that of a standard truck, and the engine and transmission units are designed to produce the necessary power for pulling a loaded semitrailer. Truck tractors may be designed with the cab over the engine, or may be of conventional truck design, with either single or dual rear axles. The flexible hose connecting the brake system of the tractor to the trailer is shown clearly at the rear of the tractor cab (fig. 38-2).

38-2. Kingpin and Plate. A heavy steel plate assembly (fig. 38-3), known as the upper fifth-wheel plate, is attached securely to the underside of the front end of the semitrailer frame. This plate serves as the bearing, or front end, support of the semitrailer when it is coupled to a tractor. The front edge of the plate is turned up approximately 45 degrees to form a skid that slides on the lower fifth-wheel plate (mounted on the truck tractor) when the semitrailer is being hitched to the truck tractor. In the center of the upper fifth-wheel plate

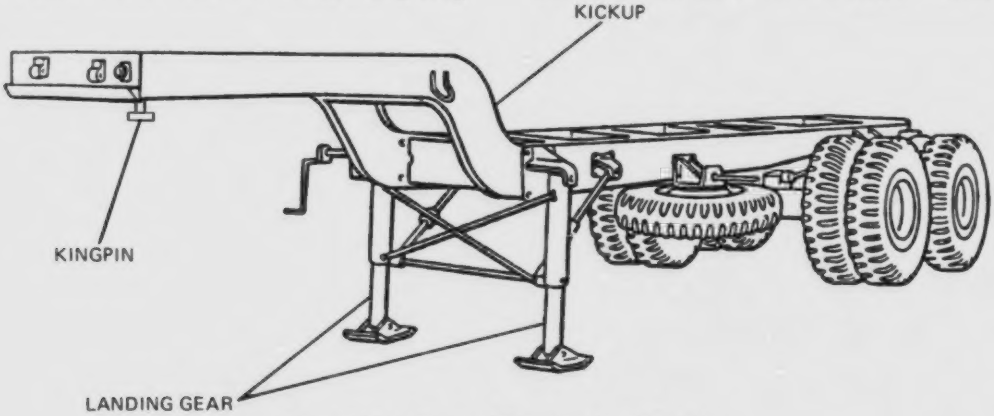


Figure 38-1. Typical Semitrailer Chassis.

TA233925

698

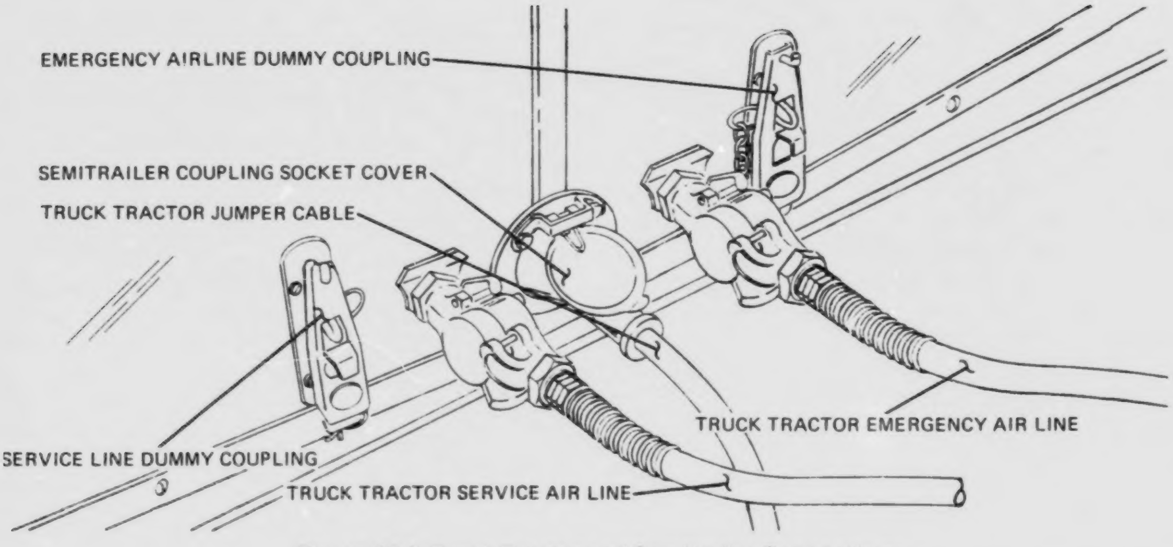

EMERGENCY AIRLINE DUMMY COUPLING
SEMITRAILER COUPLING SOCKET COVER
TRUCK TRACTOR JUMPER CABLE
TRUCK TRACTOR EMERGENCY AIR LINE
SERVICE LINE DUMMY COUPLING
TRUCK TRACTOR SERVICE AIR LINE

Figure 38-2. Truck Tractor and Semitrailer Connections.

is a permanently attached kingpin by which the truck tractor pulls the semitrailer (fig. 38-3).

38-3. Fifth Wheel. The lower fifth wheel (fig. 38-4) contains the movable parts of the fifth-wheel assembly and supports the semitrailer load thrust on the truck tractor. The circular portion of the heavy cast steel plate is the bearing surface upon which the upper plate of the semitrailer rides. The circular groove in the lower plate is a grease retainer for lubricating the rubbing surfaces of the upper and lower plates. The sloping ramps aid in picking up the upper plate of the semitrailer. The wide-open space between the ramps guides the kingpin into place. The lower plate is pivoted on a rocker pin crosswise to the truck tractor, providing a free swinging movement between the semitrailer and truck tractor. The outer ends of the rocker pin are supported in pillow blocks bolted to a bedplate, which is mounted on the frame of the truck tractor.

There are three types of fifth-wheel couplings: permanent, semiautomatic, and automatic. In a permanent fifth-wheel coupling, the kingpin is made part of the lower fifth-wheel plate, and, once it is locked in position, the truck tractor is operated with the same semitrailer at all times. In semiautomatic and automatic fifth-wheel couplings, the kingpin is contained on the upper fifth-wheel plate. The kingpin is locked in position by a kingpin lock, which is a ring on the lower fifth wheel that clamps around the kingpin. In the semiautomatic coupling, which is the most popular type, the kingpin lock (fig. 38-4) is operated by a hand lever that extends to the side of the lower fifth wheel. The automatic coupling is locked in a

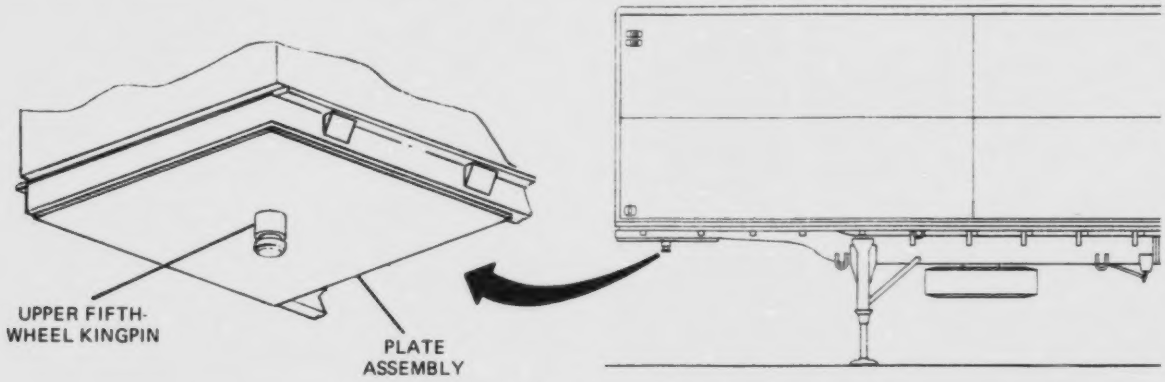

UPPER FIFTH-WHEEL KINGPIN
PLATE ASSEMBLY

Figure 38-3. Kingpin and Plate.

TA233926

699

BEST COPY AVAILABLE

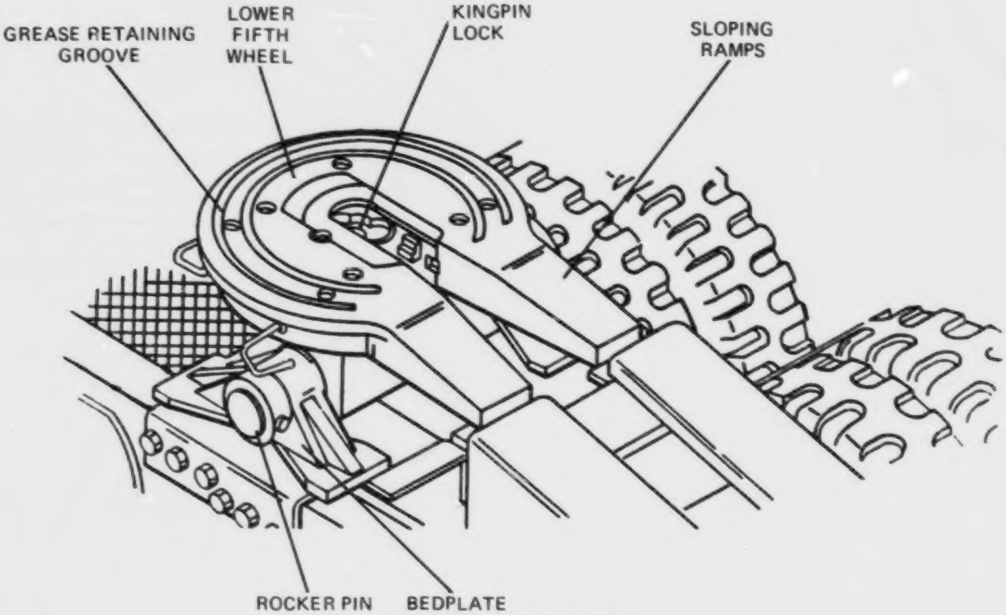


Figure 38-4. Fifth Wheel.

similar manner, except that it is controlled by the operator from the truck tractor cab.

38-4. Landing Gear. The landing gear (fig. 38-5) is a retractable support under the front end of a semitrailer to hold it up when it is uncoupled from the truck tractor. The two leg members of the landing gear usually are attached to the underside of the trailer chassis by pivot pins. These leg members are connected together by cross braces to resist any side strains. Two small steel wheels, mounted on the end of these leg members, facilitate moving the semitrailer about when it is uncoupled from the tractor. Bracing members connect the lower end of the leg members to a movable bracket containing a nut that rides on a wormshaft located lengthwise between the side members of the trailer frame. Rotation of the wormshaft moves the bracket forward or backward (depending on the direction of rotation) and consequently lowers or raises the landing gear wheels. The landing gear (fig. 38-5) is shown in its lowered position (semitrailer uncoupled from truck tractor).

The wormshaft is supported by bearings in a housing mounted on the underside of the semitrailer chassis. It is rotated by means of a set of bevel gears at the forward end of the housing.

These gears are turned by a hand-operated lever at the end of a shaft that extends out to the side of the semitrailer.

The height to which the landing gear lifts the front end of the semitrailer above the ground can be varied by adjustable clamps at the top of the two leg members. This adjustment is necessary if the semitrailer is to be used with truck tractors having different rear end heights.

When semitrailers are coupled and uncoupled, it is important that the landing gear be coordinated with the fifth-wheel lock. If the landing gear is elevated before the fifth-wheel connection is locked fully, the front end of the semitrailer will drop to the ground when the truck tractor is driven away, with the possibility of damaging both the load and the semitrailer. Before the semitrailer is uncoupled, the brake coupling should be disconnected so that the semitrailer brakes are applied to prevent it from moving. Automatic controls sometimes are used to coordinate the desired features. Auxiliary locking pins strike against the lower fifth-wheel plate on the truck tractor and lock the fifth-wheel connection, preventing the trailer from being separated until the landing gear is lowered fully. These auxiliary locking pins are connected by an actuating rod in such a way that they cannot be raised to unlock the fifth-wheel connection until the landing gear is lowered fully and the semitrailer brakes are applied.

TA233927

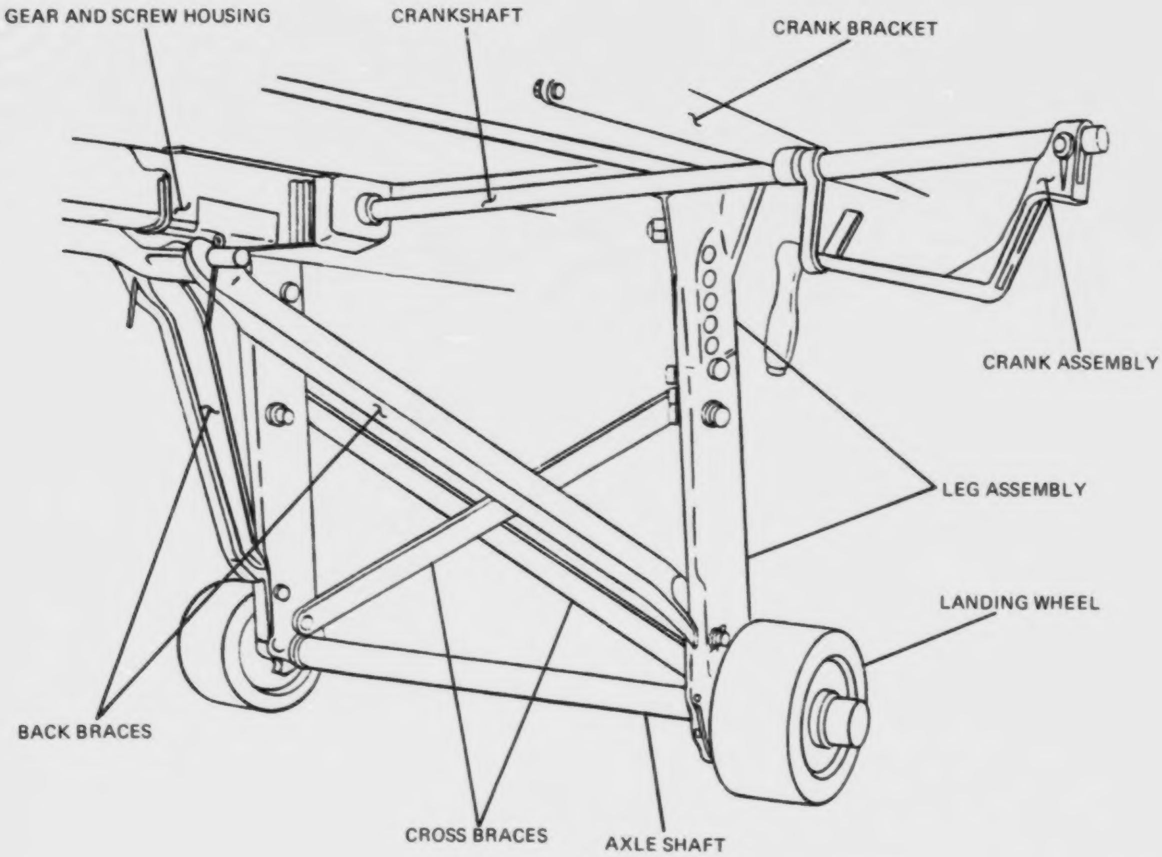


Figure 38-5. Landing Gear.

Section II. THREE-QUARTER TRAILERS

38-5. General Description. Three-quarter trailers (usually two-wheel) are used for light loads. The entire trailer load is balanced on the trailer suspension. Usually approximately 15 percent of the trailer load is thrust on the tractor connection. Three-quarter trailers are built in many sizes and are fitted with various forms of bodies ranging from the general pickup and tank (fuel and water) to the more elaborate house trailers used as hospital and recruiting vehicles. In some of the heavier types, tandem axles are employed to carry the load.

Two different types of three-quarter trailers are illustrated in figure 38-6. The frame and body form an integral unit. The crossmembers underneath the body reinforce the floorboard and form the rear section of the frame.

38-6. Drawbar. The drawbar (fig. 38-6) connects the front end of the trailer body to the coupling device. It also serves as a mounting location for the landing gear. In some cases, a storage box is mounted to the drawbar to house the intervehicular cable and accessories.

38-7. Lunette. The lunette (fig. 38-6) is the eye assembly mounted to the front of the drawbar. Its circular shape allows it to be coupled to the pintle assembly on the tow vehicle with ease.

38-8. Landing Gear. The landing gear (fig. 38-6) is used to support the front of the trailer when uncoupled from the tow vehicle. The landing gear wheel rotates on a shaft held by a yoke that is free to turn horizontally. The yoke also

TA233928

701

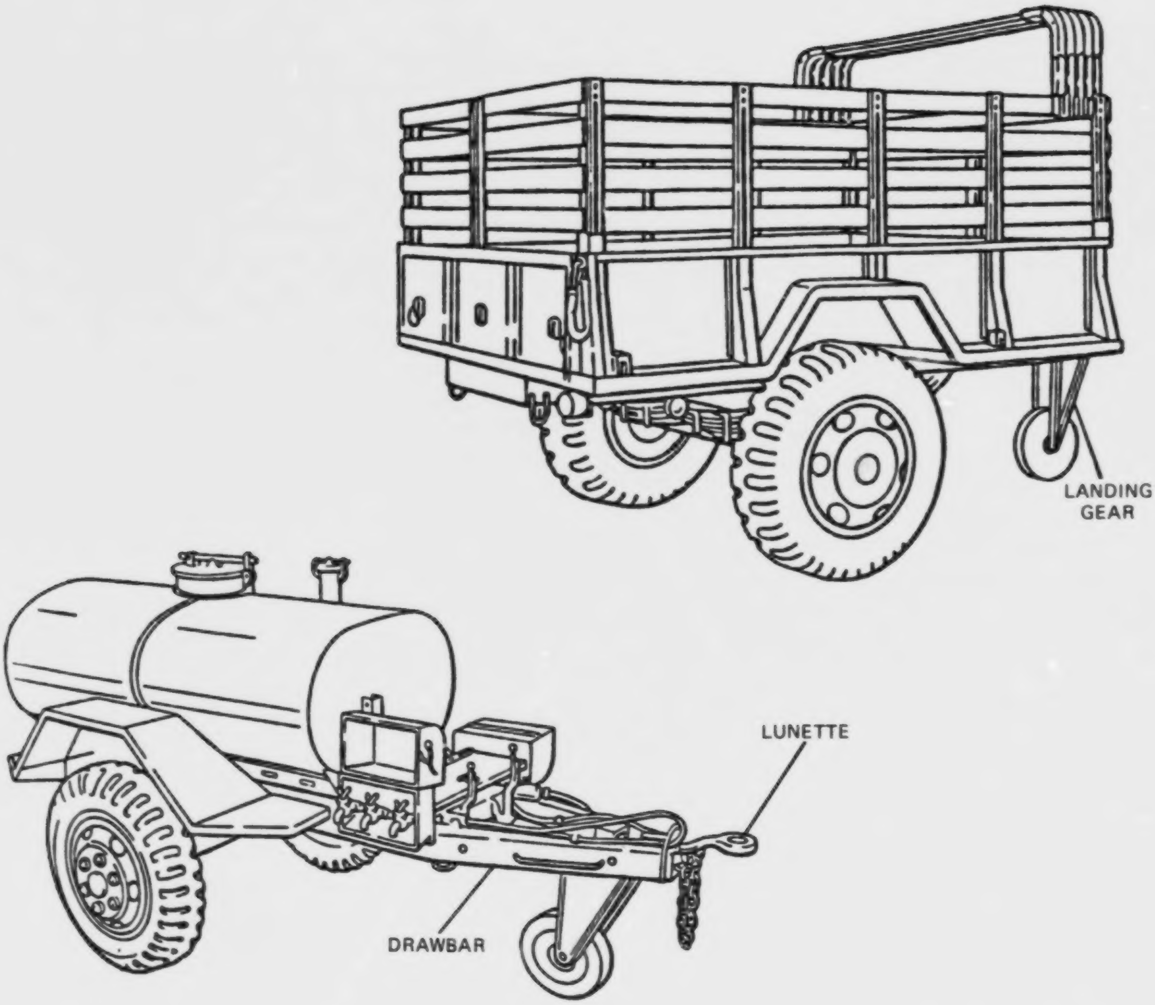


Figure 38-6. Typical Three-Quarter Trailers.

is pivoted to a landing gear casting so that the wheel may be raised or lowered. A removable pin can be placed in various holes of the yoke to hold the wheel at the desired height.

Section III. FULL TRAILER

38-9. General Description. Full trailers, which support their entire load, may be connected directly behind the towing vehicle to a semitrailer or to another full trailer. They are independent and fully contained vehicles without motive power.

Early full trailers were equipped with knuckle or Ackerman steering used on motor vehicles, but all full trailers now use fifth-wheel steering. Many full trailers are constructed with a simple type of fifth-wheel consisting of two large steel plates and a kingpin. In a heavily loaded trailer, considerable binding between the fifth-wheel plates hinders free steering, so when the driver steers the motor vehicle to the right or left, the binding fifth-wheel resists the turning effort and tends to keep the motor vehicle traveling straight ahead. This is apparent to the driver when operating on slippery roads and makes steering not only difficult, but dangerous. To overcome this, there is a tendency toward more refined fifth-wheel designs that will turn freely under heavy loads by the use of bearings.

TA233929

702

a. Full Trailer. Full trailers may be classified as nonreversible, reversible, and converted semitrailers. A nonreversible full trailer can be towed and steered from one end only. Its frame is supported by front and rear two-wheel trucks that consist of a square frame made of channel sections containing the spring hangers. The rear truck is bolted to the trailer frame and forms an integral part of the chassis. A lower fifth-wheel ring mounted on top of the front truck fits together with an upper fifth-wheel ring attached underneath the front end of the trailer frame. The front truck, therefore, turns around the fifth wheel, which allows the trailer to be steered. A towing tongue is pivoted to the front truck, and the other end contains a lunette that connects with the pintle hook of the towing vehicle. The trailer chassis illustrated in figure 38-7 is equipped with electrical and airbrake connections, which are hooked up to the towing vehicle. A safety chain is provided to prevent the trailer from running away if the pintle hook connection should break loose.

A reversible full trailer may be towed or steered from either end. It is similar to the nonreversible trailer in construction and appearance, except that both front and rear trucks are mounted by fifth wheels. The towing tongue is detachable and may be used with either truck. Both trucks are provided with locks so that one may be prevented from turning when the other is connected to the towing ends, thus increasing the operating flexibility of the trailer.

b. Semitrailer Converted to a Full Trailer. A semitrailer may be converted to a full trailer by mounting the fifth wheel on a dolly (fig. 38-8) and using the dolly in place of a tractor as the semitrailer front end support. This combination is known as a converted semitrailer. The dolly is a short two-wheel trailer chassis with a standard lower fifth wheel mounted on its frame.

The front end of its frame is tapered to receive a bracket that contains a lunette for towing the trailer by a pintle assembly. A retractable landing gear supports the front end of the dolly when not in use. The open hooks on either side at the front end of the frame are used for joining the towing vehicle and the trailer with safety chains.

The rear-end view of a heavy-duty vehicle (fig. 38-9), used for towing three-quarter and full trailers, illustrates the pintle assembly. The rear bumpers protect the frame of the vehicle and guide the trailer lunette (towing hook) into the pintle assembly during the trailer coupling operation. The electric brake lead of the trailer is plugged into the electric brake connection, shown with the cover open. The airbrake connections enable the airbraking system of the towing vehicle to be joined to that of the trailer when the trailer is equipped with airbrakes. The airbrake connection is shown with its cap removed, as it would appear when ready for coupling.

38-10. Drawbar and Lunette. The drawbar and lunette used on full trailers are similar to those used on three-quarter trailers described in paragraphs 38-6 and 38-7.

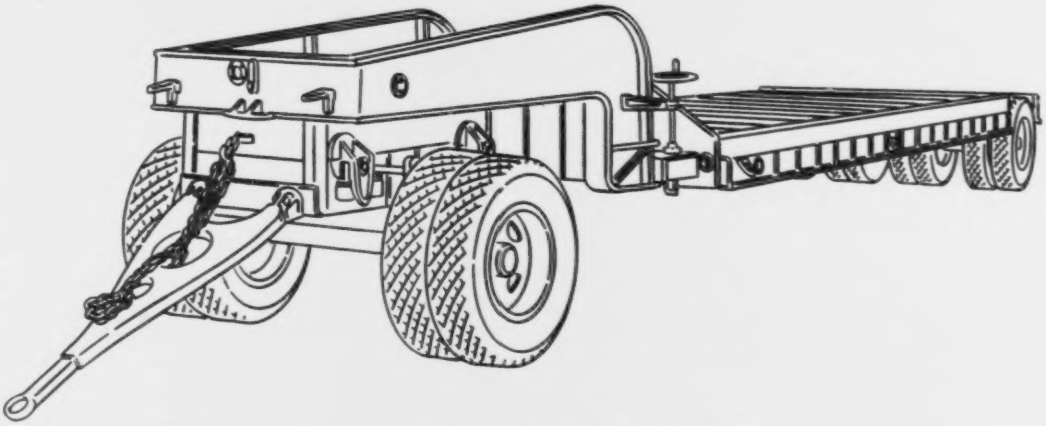


Figure 38-7. Typical Full-Trailer Chassis.

TA233930

703

BEST COPY AVAILABLE

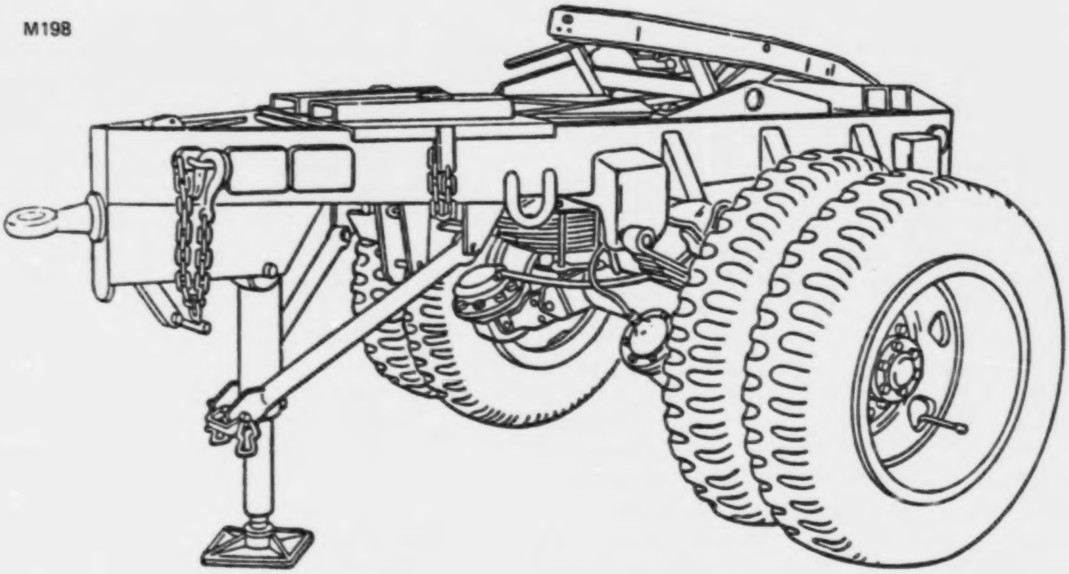


Figure 38-8. Trailer Converter Dolly.

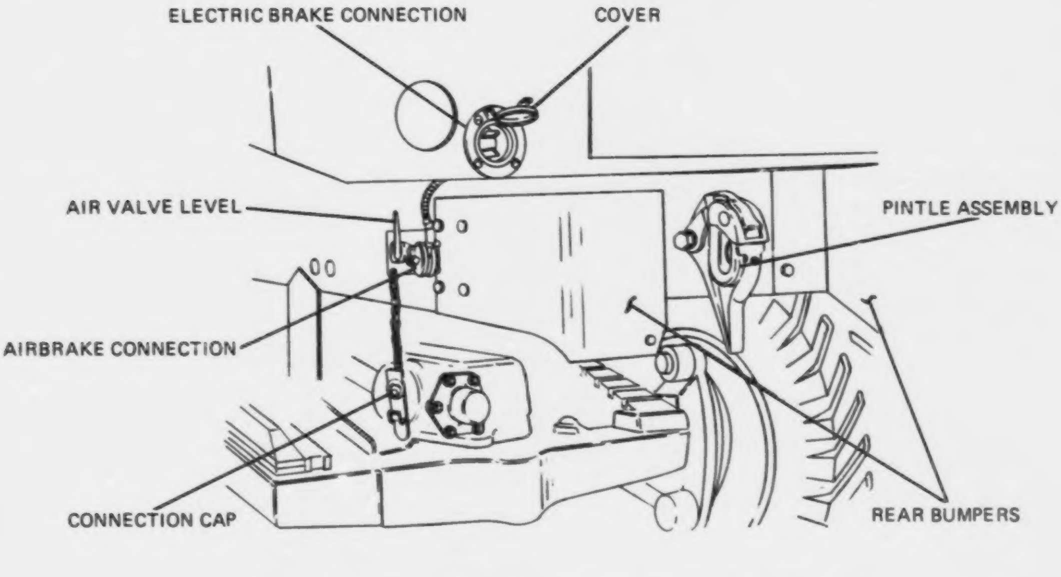

ELECTRIC BRAKE CONNECTION
COVER
AIR VALVE LEVEL
PINTLE ASSEMBLY
AIRBRAKE CONNECTION
CONNECTION CAP
REAR BUMPERS

Figure 38-9. Tow Vehicle for Three-Quarter and Full Trailers.

TA233931

704

BEST COPY AVAILABLE

Section IV. MATCHING TOWING VEHICLE TO TRAILER

38-11. Matching Brake and Electrical Systems. Matching a towing vehicle and a trailer means more than coupling them. The brake and electrical systems must match. Furthermore, the trailer load must not exceed the performance of the towing vehicle.

38-12. Matching Electrical Systems. The towing vehicle and trailer electrical systems must be of the same voltage. If the towing vehicle has a 6-volt system, the trailer must have a 6-volt system. Likewise, if one has a 12-volt system, the other must have a 12-volt system. Connecting 6-volt lights into a 12-volt system will cause them to burn out as soon as they are turned on. On the other hand, 12-volt lights connected to a 6-volt source will give little or no light.

38-13. Matching Brake Systems. The brake systems also must match. If the towing vehicle has an air-pressure brake system, the trailer must also have an air-pressure brake system. Likewise, if the towing vehicle has a vacuum-type or an electric braking system, the trailer must have a matching braking system.

38-14. Matching Load and Performance. To avoid overloading the towing vehicle, excessive loads must not be hitched to it. The trailer load must not be above that which the towing vehicle was designed to pull. The technical manual of the towing vehicle usually has the maximum trailer load listed in the tabulated data section. If it does not, the drawbar pull can be calculated as explained in paragraph 29-15c.

APPENDIX

DEFINITION OF TERMS

ABCD. After bottom dead center.

AC. Alternating current, or current that reverses its direction at regular intervals.

Accelerating Pump. A device in the carburetor that supplies an additional amount of fuel, temporarily enriching the fuel-air mixture when the throttle is suddenly opened.

Acceleration. The process of increasing velocity. Average rate of change of increasing velocity, usually in feet per second.

Accelerator. Pedal and linkage used to control engine speed.

Accumulator. A container used in an air conditioning system to filter and remove moisture.

Accumulator Piston. A unit in the automatic transmission used to apply the brake band quickly and smoothly.

Ackerman Steering. The steering system design that permits the front wheels to round a turn without sideslip by turning the inner wheel in more than the outer wheel.

Air Bleed. A passage in the carburetor through which air can seep or bleed into fuel moving through a fuel passage.

Airbrakes. Vehicle brakes actuated by air pressure.

Air Cleaner. A device, mounted on the carburetor or connected to the carburetor, through which air must pass before entering the carburetor air horn. A filtering device in the air cleaner removes dust and dirt particles from the air.

Air Conditioning. A system designed to provide control over air temperature, movement, and humidity.

Air-Cooled Engine. An engine cooled by air circulating between cylinders and around cylinder head as opposed to the liquid-cooled engine cooled by a liquid passing through jackets surrounding the cylinders.

Air Filter. A filter through which air passes, and which removes dust and dirt particles from the air. Air filters are placed in passages through which air must pass, as in crankcase breather, air cleaner, etc.

Air-Fuel Ratio. The ratio between the volume of air and the volume of fuel used to establish the combustion mixture.

Air Horn. That part of the air passage in the carburetor that is on the atmospheric side of the venturi. The choke valve is located in the air horn.

Air-Pac Brakes. A type of braking system using a vacuum.

Alloy. A mixture of two or more materials.

Alternator. A device similar to a generator but which produces ac current.

Ambient Temperature. The temperature of the environment surrounding an object.

Ammeter. An electric meter that measures current, in amperes, in an electric circuit.

Ampere. Unit of electric-current-flow measurement. The current that will flow through a 1-ohm resistance when 1 volt is impressed across the resistance.

Amphibious Vehicle. A vehicle with a hull that permits it to float in water, and tracks or wheels that permit it to travel on land.

Angle of Approach. The maximum angle of an incline onto which a vehicle can move from a horizontal plane without interference; as, for instance, from front bumpers.

Angle of Departure. The maximum angle of an incline from which a vehicle can move onto a horizontal plane without interference; as, for instance, from rear bumpers.

706

DEFINITION OF TERMS – CONTINUED

Antifreeze. A substance added to the coolant system in a liquid-cooled engine to prevent freezing.

Antifriction Bearing. A bearing of the type that supports the imposed load on rolling surfaces (balls, rollers, needles), minimizing friction.

Antiknock. Refers to substances that are added to automotive fuel to decrease the tendency to knock when fuel-air mixture is compressed and ignited in the engine cylinder.

Armature. The rotating assembly in a direct current generator or motor. Also, the iron piece in certain electrical apparatus that completes a magnetic, and in many cases, an electric, circuit.

Asbestos. A fibrous material that resists heat and burning.

ATDC. After top dead center.

Atmosphere. The mass of air that surrounds the earth.

Atmospheric Pressure. The weight of the atmosphere per unit area.

Atom. The smallest particle, or part, of an element, composed of electrons and protons and also of neutrons (with the exception of hydrogen).

Atomization. The spraying of a liquid through a nozzle so that the liquid is broken into tiny globules or particles.

Automatic Choke. A choke that operates automatically in accordance with certain engine conditions, usually temperature and intake manifold vacuum (also electrically controlled).

Automatic Leveling Control. A system designed to maintain proper riding height, regardless of changes in vehicle load.

Automatic Transmission. A transmission that reduces or eliminates the necessity of hand shifting of gears to secure different gear ratios in the transmission.

Axial. In a direction parallel to the axis. Axial movement is movement parallel to the axis.

Axis. A centerline. The line about which something rotates or about which something is evenly divided.

Axle. A cross support on a vehicle on which supporting wheel, or wheels, turn. There are two general types: live axles that also transmit power to the wheels, and dead axles that transmit no power.

Backfiring. Preexplosion of fuel-air mixture so that explosion passes back around the opened intake valve and flashes back through the intake manifold.

Backlash. The backward rotation of a driven gear that is permitted by clearance between meshing teeth of two gears.

Back Pressure. The resistance of gases to flow through a system.

Baffle. A plate or shield to divert the flow of liquid or gas.

Ballast. A resistor that changes voltage in direct proportion to heat of wire.

Ball Bearing. A type of bearing that contains steel balls that roll between inner and outer races.

Battery. A device consisting of two or more cells for converting chemical energy into electrical energy.

Battery Capacity. Rating of a battery's current output.

Battery Charging. The process of supplying a battery with a flow of electric current to produce chemical actions in the battery; these actions reactivate the chemicals in the battery so they can produce electrical energy again.

Battery, Maintenance-Free. A battery that does not require addition of water during its normal life.

Battery Rating. A standardized measurement of a battery's ability to deliver electrical power under certain conditions.

DEFINITION OF TERMS – CONTINUED

BBCD. Before bottom dead center.

BDC. Bottom dead center; the position of the piston when it reaches the lower limit of travel in the cylinder.

Bead. The circular wire-reinforced section of a tire that joins with the wheel rim.

Bearing. A part in which a journal pivot, or pin, turns or revolves. A part on or in which another part slides.

Bendix Drive. A type of drive used in a starter that provides automatic coupling with the engine flywheel for cranking and automatic uncoupling when the engine starts.

Bevel Gear. One of a pair of meshing gears whose working surfaces are inclined to the centerlines of the driving and driven shafts.

Bezel. A device used to attach a glass face to an instrument.

Blackout Lights. A lamp installed on a vehicle for use during blackouts, which can be seen from the air only at very close range.

Block. See Cylinder Block.

Blowby. Leakage of the compressed fuel-air mixture or burned gases from combustion, passing piston and rings, and into the crankcase.

Blower. A mechanical device for compressing and delivering air to engine at higher than atmospheric pressure.

Body. The assembly of sheet metal sections, framework, doors, windows, etc, which provides an enclosure for passengers or carriage space for freight.

Bogie. A suspension unit consisting of tandem axles jointed by a single cross support (trunnion axle) that also acts as a vertical pivot for the entire unit.

Boiling Point. The temperature at which a liquid boils.

Bond. To bind together.

Bore. The diameter of an engine cylinder hole. Also, the diameter of any hole; as, for example, the hole into which a bushing is fitted.

Boss. An extension or strengthened section, such as the projections within a piston which supports the piston pin.

Bottled Gas. A gas that remains a liquid when confined in a tank under pressure.

Bound Electrons. Electrons located in the inner orbits around the nucleus of an atom.

Bourdon Tube. A hollow circular-shaped tube used as the pressure-sensing element in some gages.

Brake Anchor. A steel pin-shaped stud, rigidly mounted to the backing plate, upon which the brakeshoe either is attached or rests against.

Brake Backing Plate. A rigid steel plate upon which certain brake components are attached.

Brake Band. A flexible band, usually of metal with an inner lining of brake fabric, that is tightened on a drum to slow or stop drum rotation.

Brake, Disk-Type. A braking network consisting of a rotating disk that is restrained during application by stationary brake pads mounted on both sides of the disk.

Brakedrum. A metal drum mounted on a car wheel or other rotating members; brakeshoes or brake band, mechanically forced against it, cause it to slow or stop.

Brake Fade. A reduction in the coefficient of friction between retarding members as a result of excessive heat buildup.

Brake Fluid. A compounded fluid used in hydraulic braking system; it transmits hydraulic force from the brake master cylinder to the wheel cylinder.

Brake Horsepower. The power actually delivered by the engine that is available for driving the vehicle.

DEFINITION OF TERMS – CONTINUED

Brake Hose. A tubular hose used to transmit fluid pressure when a flexible joint is required.

Brake Line. A rigid tube used to carry brake fluid.

Brake Lining. A special woven fabric material with which brakeshoes or brake bands are lined: it withstands high temperatures and pressures.

Breaker Points. An adjustable cam-operated switch inside the distributor used to trigger the coil.

Brakes. The mechanism that slows or stops a vehicle or mechanism when a pedal or other control is operated. Also called the brake system.

Brakeshoes. The curved metal part, faced with brake lining, that is forced against the brakedrum to produce braking or retarding action.

Brake System. The system on a vehicle that slows or stops it as a pedal or lever is operated.

Bronze. An alloy consisting essentially of copper and tin.

Brushes. The carbon or carbon and metal parts in a motor or generator that contact the rotating armature commutator or rings.

BTDC. Before top dead center.

Bushing. A sleeve placed in a bore to serve as a bearing surface.

Bypass. A separate passage that permits a liquid, gas, or electric current to take a path other than that normally used.

Cab. Separate driver's compartment provided on trucks.

Caliper. A disk brake component used to house the piston(s) and brake pads.

Cam. A moving part of an irregular form designed to move or alter the motion of another part.

Camber. To curve or bend; the amount in inches or degrees that the front wheels of an automotive vehicle are tilted from a true vertical at the top.

Cam-Ground. A process by which the piston is ground slightly egg-shaped and, when heated, becomes round.

Camshaft. A shaft with cam lobes used to operate valves.

Capacitance. That property of a circuit that tends to increase the amount of current flowing in a circuit for a given voltage or to delete in its entirety.

Capacitor (Condenser). A device for inserting the property of capacitance into a circuit; two or more conductors separated by a dielectric.

Carbon Monoxide. A colorless, odorless, tasteless, deadly gas found in engine exhaust. This gas is formed by incomplete burning of hydrocarbons.

Carbon-Pile Regulator. A type of regulator for regulating or controlling voltage or amperage in a circuit, which makes use of a stack, or pile, or carbon disks.

Carburetor. The device in a fuel system that mixes fuel and air and delivers the combustible mixture to the intake manifold.

Caster. The amount in degrees that the steering knuckle pivots are tilted forward or backward from a true vertical.

Casting. Pouring metal into a mold to form an object.

Catalytic Converter. A device used on some exhaust systems to reduce harmful emissions.

Cell. A combination of electrodes and an electrolyte that converts chemical energy into electrical energy; two or more cells connected together form a battery.

Center Link. Also referred to as a relay rod used to transmit motion from pitman arm to tie rods.

Center Steering Linkage. A steering system configuration using two tie rods connected to steering arms and to a central idler arm; the idler arm pivots on the frame on one end and is connected to the drag link on the other.

DEFINITION OF TERMS – CONTINUED

Centrifugal Advance. The mechanism in an ignition distributor by which the spark is advanced or retarded as the engine speed varies.

Centrifugal Force. The force acting on a rotating body, which tends to move its parts outward and away from the center of rotation.

CFM. Cubic feet per minute.

Charge Indicator. The device on a vehicle that indicates, by a needle, whether or not the battery is receiving a charge from the generator.

Charging Rate. The rate of flow, in amperes, of electric current flowing through a battery while it is being charged.

Chassis. An assembly of mechanisms, attached to a frame, that make up the major operating part of an automotive vehicle (less body).

Choke. A device in the carburetor that chokes off, or reduces, the flow of air into the intake manifold; this produces a partial vacuum in the intake manifold and a consequent richer fuel-air mixture.

Choke Stove. A device used to draw heat from around the exhaust manifold into the carburetor during engine warmup.

CID. Cubic inch displacement.

Circuit. A closed path or combination of paths through which passage of the medium (electric current, air, liquid, etc) is possible.

Circuit Breaker. In electric circuits, a mechanism designed to break or open the circuit when certain conditions exist; especially the device in automotive circuits that opens the circuit between the generator and battery to prevent overcharging of the battery. (One of the three units comprising a generator regulator.)

Clearance. A given amount of space between two parts.

Clockwise. The direction of movement, usually rotary, which is the same as movement of hands on the face of a clock.

Clutch. The mechanism in an automotive vehicle, located in the power train, that connects the engine to, or disconnects the engine from, the remainder of the power train.

Coil. In electrical circuits, turns of wire, usually on a core and enclosed in a case, through which electric current passes.

Coil Spring. A type of spring made of an elastic metal such as steel, formed into a wire or bar and wound into a coil.

Combat Vehicle. A type of vehicle, usually armored, for use in armed combat.

Combustion. A chemical action, or burning; in an engine, the burning of a fuel-air mixture in the combustion chamber.

Combustion Chamber. The space at the top of the cylinder and in the head in which combustion of the fuel-air mixture takes place.

Commutation. The process of converting alternating current that flows in the armature windings of direct current generators into direct current.

Commutator. That part of rotating machinery that makes electrical contact with the brushes and connects the armature windings with the external circuit.

Compensating Port. A small hole in the brake master cylinder to permit fluid to return to the reservoir.

Compression. The act of pressing into a smaller space or reducing in size or volume by pressure.

Compression Ratio. The ratio between the volume in the cylinder with the piston at bottom dead center and with the piston at top dead center.

Compression Rings. The upper rings on a piston; the rings designed to hold the compression in the cylinder and prevent blowby.

Compression Stroke. The piston stroke from bottom dead center to top dead center during which both valves are closed and the gases in the cylinder are compressed.

710

DEFINITION OF TERMS – CONTINUED

Compressor. A device used to increase pressure.

Concentric. Having a common center, as circles or spheres, one within the other.

Condense. To transform a vapor into a liquid.

Condenser. 1. See Capacitor. 2. A unit used in refrigeration systems that removes heat of compression from a gas to return it to a liquid state.

Conductor. A material through which electricity will flow readily.

Connecting Rod. Linkage between the crankshaft and piston, usually attached to the piston by a piston pin and to the crank journal on the crankshaft by a split bearing and bearing cap.

Control Rack. A toothed rod inside mechanical injection pumps that rotates the pump plunger to control the quantity of injected fuel.

Coolant. The liquid that circulates in an engine cooling system that reduces heat generated by the engine.

Cooling Fan. The fan in the engine cooling system that provides a forced circulation of air through the radiator or around the engine cylinders so that cooling is affected.

Cooling Fins. The thin metal projections on the air-cooled engine cylinder and head that greatly increases the heat-radiating surfaces and helps provide cooling of engine cylinder.

Cooling System. A system that reduces heat generated by the engine and thereby prevents engine overheating; includes, in liquid-cooled engine, engine water jackets, radiator, and water pump.

Core. An iron mass, generally the central portion of a coil or electromagnet or armature around which the wire is coiled.

Counterbalance. A weight attached to a moving part so it will be in balance.

Counterclockwise. The direction of movement, usually rotary, which is opposite in direction to movement of hands on the face of a clock.

Cowl. The front portion of the vehicle body or cab that partially encloses the dash panel and forms the windshield frame.

Crank. A device for converting reciprocating motion into rotary motion, and vice versa.

Crankcase. The lower part of the engine in which the crankshaft rotates. In automotive practice, the upper part is the lower section of the cylinder block, while the lower section is the oil pan.

Crankcase Breather. The opening or tube that allows air to enter the crankcase and thus permits crankcase ventilation.

Crankcase Dilution. Dilution of the lubricating oil in the oil pan by liquid gasoline seeping down the cylinder walls past the piston rings.

Crankcase Ventilation. The circulation of air through the crankcase, which removes water and other vapors, thereby preventing the formation of water sludge and other unwanted substances.

Cranking Motor. See Starter.

Crankshaft. The main rotating member or shaft of the engine, with cranks to which the connecting rods are attached.

Cross-Drive Transmission. A special type of transmission used in tanks and other heavy vehicles that combines the actions of a transmission with torque converter, steering system, and differential.

Current Regulator. A magnetic-controlled relay by which the field circuit of the generator is made and broken very rapidly to secure even current output from the generator and to prevent generator overload from excessive output. (One of the three units comprising a generator regulator.)

Cutout Relay. 1. See Circuit Breaker. 2. An automatic magnetic switch attached to the generator to cut out generator circuit and prevent overcharging of battery.

711

DEFINITION OF TERMS – CONTINUED

Cycle. A series of events with a start and finish during which a definite train of events takes place. In the engine, the four piston strokes (or two piston strokes on two-stroke cycle engine) that complete the working process and produce power.

Cylinder. A tubular-shaped structure. In the engine, the tubular opening in which the piston moves up and down.

Cylinder Block. That part of an engine to which, and in which, other engine parts and accessories are attached or assembled.

Cylinder Head. The part of the engine that encloses the cylinder bores; contains water jackets (on liquid-cooled engines) and valves (on I-head engines).

Cylinder Sleeve. A pipe-shaped removable insert used as the cylinder wall on some engines.

Damper. A device for reducing the motion or oscillations of moving parts, air, or liquid.

Dash Panel. The partition that separates the driver's compartment from the engine compartment. Sometimes called firewall.

Dashpot. A unit used to slow down movement or arrest vibrations or oscillations of a moving part.

DC. Direct current, or current that flows in one direction only.

Dead Axle. An axle that simply supports and does not turn or deliver power to the wheel or rotating member.

Deceleration. The process of slowing down; opposite of acceleration.

Degasser. A device used in connection with carburetors for shutting off the flow of fuel during deceleration so that gases from incomplete combustion during deceleration are prevented.

Desiccant. A substance used to absorb and retain moisture.

Detonation. In the engine, excessively rapid burning of the compressed fuel-air mixture so that knocking results.

Diaphragm. A flexible membrane, usually made of fabric and rubber in automotive components, clamped at the edges and usually spring-loaded; used in fuel pump, vacuum pump, distributor, etc.

Diesel Engine. An engine using the diesel cycle of operation; air alone is compressed and diesel fuel is injected at the end of the compression stroke. Heat of compression produces ignition.

Dieseling. A condition in which an engine continues to run after the ignition is turned off. Also referred to as engine run-on.

Differential. A mechanism between axles that permits one axle to turn at a different speed than the other and, at the same time, transmits power from the driving shaft to the axles.

Differential Winding. In electrical machinery, a winding that is wound in a reverse direction or different direction than the main operating windings. The differential winding acts to modify or change the action of the machine under certain conditions.

Diode. A device that permits current flow in one direction and resists flow in the other.

Disk Brake. A braking network that uses a rotating disk called a rotor and stationary brake pads such that when forced together perform a retarding action.

Disk Wheel. A wheel constructed of stamped steel.

Displacement. The total amount of air or liquid an object consumes while moving from one location to another.

Distribution Tubes. Tubes in the cooling system used to direct coolant flow to vital areas.

Distributor. See Ignition Distibutor.

DOHC. Double overhead camshaft.

712

DEFINITION OF TERMS – CONTINUED

Dolly. A two-wheel trailer coupled to a semitrailer to support and steer its front end when it is converted into a full trailer.

Drag Link. An intermediate link in the steering system between the pitman arm and an intermediate arm, or drag-link arm.

Drive Shaft. A shaft used to transmit rotary motion.

Drop Center Rim. A rim in which the center section is closer to the center of the rim than the two outer edges.

Drop Forged. A part that has been formed by heating until red hot and pounding with a hammer.

Dry Sleeve. A cylinder sleeve that is supported its entire length by the block; coolant does not contact the sleeve in this configuration.

Dry Sump. An oiling system that uses a scavenger pump to collect oil and transfer it to an auxiliary container or sump.

Dual Ignition. An ignition system using two spark plugs for each cylinder so that a dual spark effect takes place, driving each power stroke.

Dual-Ratio Axles. An axle in a truck that contains a mechanism for changing driving ratio of the wheels to either high or low ratio. Two-speed differential.

Dynamometer. A device for measuring the power output of an engine.

Eccentric. Offcenter.

Eddy Currents. Currents that are induced in an iron core and circulate in the core.

Efficiency. The ratio between the effect produced and the power expended to produce the effect.

Electric Brakes. A brake system that uses electric current for energization.

Electrical System. In the automotive vehicle, the system that electrically cranks the engine for starting, furnishes high-voltage sparks to the engine cylinders to fire compressed fuel-air charges, lights the lights, and operates heater motor, radio, etc. Consists, in part, of starter, wiring, battery, generator, generator regulator, ignition distributor, and ignition coil.

Electricity. A form of energy that involves the movement of electrons from one place to another, or the gathering of electrons in one area.

Electrode. Either terminal of an electric source; either conductor by which the current enters and leaves an electrolyte.

Electrolyte. The liquid in a battery or other electrochemical device, in which the conduction of electricity is accompanied by chemical decomposition.

Electromagnet. A temporary magnet constructed by winding a number of turns of insulated wire into a coil or around an iron core; it is energized by a flow of electric current through the coil.

Electron. A negative-charged particle that is a basic constituent of matter and electricity. Movement of electrons is an electric current.

Electron Theory. A theory stating that electron flow is from one area to another.

EMF. Electromotive force.

Emissions. Products of automotive engine combustion that are released into the atmosphere.

Energy. The capacity for performing work.

Engine. An assembly that burns fuel to produce power; sometimes referred to as the powerplant.

Ethylene Glycol. A solution added to antifreeze to help prevent freezing.

Evaporation. The action that takes place when a liquid changes to a vapor or gas.

Evaporator. A unit in an air conditioning system used to absorb heat from a passing airstream.

DEFINITION OF TERMS – CONTINUED

Exhaust Manifold. That part of the engine that provides a series of passages through which burned gases from the engine cylinders may flow to the muffler.

Exhaust Stroke. The piston stroke from bottom dead center to top dead center during which the exhaust valve is opened so that burned gases are forced from the engine cylinder.

Exhaust Valve. The valve that opens to allow the burned gases to escape from the cylinder during the exhaust stroke.

Expansion Tank. A tank separate from the radiator used to compensate for expansion and contraction of engine coolant.

Expansion Valve. A unit used on some air conditioning systems to control flow and reduce pressure of the refrigerant.

Fan. See Cooling Fan.

Ferrous Metal. A metal that contains iron or steel.

F-Head. A type of engine with valves arranged to form an F; one valve is in the head, the other in the cylinder block.

Field. In a generator or electric motor, the area in which a magnetic flow occurs.

Field Coil. A coil of wire, wound around an iron core, that produces the magnetic field in a generator or motor when current passes through it.

Field Frame. The frame in a generator or motor into which the field coils are assembled.

Field Winding. See Field Coil.

Fifth Wheel. The flat, round, heavy steel plates (upper and lower) together with a kingpin for coupling semitrailer to truck tractor. The lower plate is mounted on the truck tractor, the upper on the semitrailer.

Filament. A fine wire inside a light bulb that emits light when current passes through it.

Filter. A device through which gas or liquid is passed; dirt, dust, and other impurities are removed by the separating action.

Final Drive. That part of the power train on tractors, truck tractor tanks, and tanklike vehicles that carries the driving power to the wheels or sprockets to produce the vehicle motion as they turn.

Firewall. The partition between the engine compartment and driver's compartment.

Firing Order. The order in which respective cylinders deliver their power strokes.

Flashpoint. The temperature at which an oil will ignite and burn.

Float. In the carburetor, the metal shell that is suspended by the fuel in the float bowl and controls a needle valve that regulates the fuel level in the bowl.

Float Bowl. A section in the carburetor used as a reservoir for gasoline and in which the float is placed.

Float Circuit. In the carburetor, the circuit that controls entry of fuel and fuel level in the float bowl.

Float Level. The height of fuel in the carburetor as set by the float.

Fluid Coupling. A coupling in the power train that connects between the engine and other power train members through a fluid.

Flux. Lines of magnetic force moving through a magnetic field.

Flywheel. The rotating metal wheel, attached to the crankshaft, that helps level out the power surges from the power strokes and also serves as part of the clutch and engine-cranking system.

Foot Pound. A unit of work done in raising 1 pound avoirdupois against the force of gravity to the height of 1 foot.

DEFINITION OF TERMS – CONTINUED

Force. The action that one body may exert upon another to change its motion or shape.

Four-Stroke-Cycle Engine. An engine that requires four piston strokes (intake, compression, power, exhaust) to make the complete cycle of events in the engine cylinder.

Frame. An assembly of metal structural parts and channel sections that support the engine and body and that is supported by the vehicle wheels.

Free Electrons. Electrons in outer orbits of an atom that are easily moved out of orbit.

Freon-12. A gas used in air conditioning and refrigeration systems.

Frequency. The number of vibrations, cycles, or changes in direction in a unit of time.

Friction. The resistance to motion between two bodies in contact with each other.

Friction Bearing. A bearing having no moving parts. The shaft that rotates simply rubs against or rides on a thin film of oil between the bearing and shaft.

Fuel. The substance that is burned to produce heat and create motion of the piston on the power stroke in an engine.

Fuel Filter. A device placed in the fuel line of the fuel system to remove dirt and other harmful solids.

Fuel Gage. An indicating device in the fuel system that indicates the amount of fuel in the fuel tank.

Fuel Injection. A fuel delivery system that sprays fuel either directly into cylinders or into the intake manifold just ahead of the cylinders.

Fuel Line. The tube or tubes connecting the fuel tank and the carburetor and through which the fuel passes.

Fuel Passage. Drilled holes in the carburetor body and tubes through which fuel passes from the float bowl to the fuel nozzles.

Fuel Pump. The mechanism in the fuel system that transfers fuel from the fuel tank to the carburetor.

Fuel Tank. The storage tank for fuel on the vehicle.

Fulcrum. The support, as a wedge-shaped piece or a hinge, about which a lever turns.

Full-Floating Axle. An axle that is designed only to deliver power to the wheel. Vehicle weight and wheel retaining are accomplished by other members.

Full Trailer. An independent and fully contained vehicle without motive power.

Fuse. A circuit-protecting device that makes use of a substance that has a low melting point. The substance melts if an overload occurs, thus protecting other devices in the system.

Fusible Link. A length of special wire inserted in a circuit to protect against excessive current draw.

Gasket. A flat strip, usually of cork or metal, or both, placed between two surfaces to provide a tight seal between them.

Gasoline. A hydrocarbon, obtained from petroleum, that is suitable as an internal combustion engine fuel.

Gear Ratio. The relative speeds at which two gears turn; the proportional rate of rotation.

Gears. Mechanical devices to transmit power or turning effort, from one shaft to another; more specifically, gears that contain teeth that engage or mesh upon turning.

Gearshift. A mechanism by which the gears in a transmission system are engaged.

Generator. In the electrical system, the device that changes mechanical energy to electrical energy for lighting lights, charging the battery, etc.

715

DEFINITION OF TERMS – CONTINUED

Generator Regulator. In the electrical system, the unit that is composed of the current regulator voltage regulator, and circuit breaker relay.

Glow Plug. A device placed in some diesel engines that glows when activated to aid in starting.

Governor. A mechanism that controls speed or other variable. Specifically, speed governors used on automotive vehicles to prevent excessive engine speed by controlling actions in the carburetor.

Grid. A lead screen or plate to which battery plate material is attached.

Ground. Connection of an electrical unit to the engine or frame to return the current to its source.

Gusset Plate. A plate at the joint of a frame structure of steel to strengthen the joint.

Half Track. A vehicle using tracks instead of wheels at the rear.

Handbrake. A brake operated by hand. Also referred to as the parking brake.

Headlight. Lights at the front of the vehicle designed to illuminate the road ahead when the vehicle is traveling forward.

Heat. A form of energy.

Heat Crossover. A passage from one exhaust manifold under carburetor to the other manifold to provide heat to the base of carburetor during warmup.

Heat Exchanger. A device used to cool or heat by transferring heat from one object to another.

Heat Stove. A metal shroud around the exhaust manifold or intake manifold that supplies the carburetor with warm air when needed.

Helical. In the shape of a helix, which is the shape of a screw thread or coil spring.

Hemispherical Combustion Chamber. A round dome-shaped combustion chamber with valves placed on opposite sides of a centrally located spark plug.

Herringbone Gears. Gears having teeth machined in a V-configuration.

High-Speed Circuit. In the carburetor, the passages through which fuel flows when the throttle valve is fully opened.

High Tension. Another term for high voltage. In the electrical system, refers to the ignition secondary circuit since this circuit produces high-voltage surges to cause sparking at the spark plugs.

Hill Holder. A device that automatically prevents the vehicle from rolling backwards down a hill when the vehicle is brought to a stop.

Horn. An electrical signaling device on the vehicle.

Horsepower. A measure of a definite amount of power; 550 foot pound per second.

Hotchkiss Drive. A type of rear live axle suspension in which the springs serve as torque members.

Hull. In a tank, the protective shell that encloses the vehicle components and occupants.

Hydraulic Brakes. A braking system that uses a fluid to transmit hydraulic pressure from a master cylinder to wheel cylinders, which then cause brakeshoe movement and braking action.

Hydraulic Steering. A steering system that uses a fluid to produce an assisting hydraulic pressure on the steering linkage, thus reducing the steering effort on the part of the driver.

Hydraulic Traversing Mechanism. A turret traversing system that makes use of hydraulic pressure to furnish the motive power to traverse the turret.

Hydraulic Valve Tappet. A valve tappet that, by means of hydraulic pressure, maintains zero valve clearance so that valve noise is reduced.

716

DEFINITION OF TERMS – CONTINUED

Hydrocarbon. A mixture of hydrogen and carbon found in vehicle emissions.

Hydromatic. A type of automatic transmission containing a fluid coupling and automatic controls for shifting from one gear ratio to another.

Hydrometer. A device to determine the specific gravity of a liquid. This indicates the freezing point of the coolant in a cooling system or, as another example, the state of charge of a battery.

Hydrovac Brakes. A type of braking system using vacuum to assist in brake operation. The vacuum action reduces the effort required from the driver to operate the vehicle brakes.

Hypoid Gearing. A type of gearing configuration in which the pinion gear meshes with the ring gear below the centerline of the ring gear.

Idle. The engine speed when the accelerator pedal is fully released; generally assumed to mean when the engine is doing no work.

Idle Circuit. The circuit in the carburetor through which fuel is fed when the engine is idling.

Idler Arm. A steering component designed to support one end of the center link.

Idler Gear. A gear placed between a driving and a driven gear to make them rotate in the same direction. It does not affect the gear ratio.

Idling Adjustment. The adjustment made on the carburetor to alter the fuel-air mixture ratio or engine speed on idle.

Ignition. The action of setting fire to; in the engine, the initiating of the combustion process in the engine cylinders.

Ignition Advance. Refers to the spark advance produced by the distributor in accordance with engine speed and intake manifold vacuum.

Ignition Coil. The component of the ignition system that acts as a transformer and steps up battery voltage to many thousand volts; the high voltage then produces a spark at the spark plug gap.

Ignition Distributor. The component of the ignition system that closes and opens the circuit between the battery and ignition coil, and distributes the resultant high-voltage surges from the coil to the proper spark plugs.

Ignition Switch. The switch in the ignition system that can be operated to open or close the ignition primary circuit.

Ignition Timing. Refers to the timing of the spark at the spark plug as related to the piston position in the engine cylinder.

I-Head. A type of engine with valves in the cylinder head.

Impeller. The rotor of a centrifugal pump that causes the fuel-air in an engine to be thrown into a diffuser chamber to effect thorough mixing and good distribution.

Independent Suspension. A type of suspension system designed to spring each wheel separately, therefore allowing each wheel to move independently from the other.

Indicated Horsepower. A measurement of engine power based on power actually developed in the engine cylinders.

Induction. The action or process of producing voltage by the relative motion of a magnetic field and a conductor.

Inhibitor. A substance added to a liquid to prevent unwanted actions.

Injector. The mechanism, including nozzle, that injects fuel into the engine combustion chamber on diesel engines.

In-Line Engine. An engine in which all engine cylinders are in a single row, or line.

Insert. A form of screw thread insert to be placed in a tapped hole into which a screw or bolt will be screwed. The insert protects the part into which the hole was tapped, preventing enlargement due to repeated removal and replacement of the bolt.

DEFINITION OF TERMS – CONTINUED

Insulation. A substance that stops movement of electricity (electrical insulation) or heat (heat insulation).

Insulator. A substance (usually of glass or porcelain) that will not conduct electricity.

Intake Manifold. That component of the engine that provides a series of passages from the carburetor to the engine cylinders through which fuel-air mixture can flow.

Intake Stroke. The piston stroke from top dead center to bottom dead center during which the intake valve is open and the cylinder receives a charge of fuel-air mixture.

Intake Valve. The valve in the engine that is opened during the intake stroke to permit the entrance of fuel-air mixture into the cylinder.

Integral. Whole; entire; lacking nothing of completeness.

Interference. In radio, any signal received that overrides or prevents normal reception of the desired signal. In mechanical practice, anything that causes mismating of parts so they cannot be normally assembled.

Internal Combustion Engine. An engine in which the fuel is burned inside the engine, as opposed to an external combustion engine where the fuel is burned outside the engine, such as a steam engine.

Internal Gear. A gear in which the teeth point inward rather than outward as with a standard spur gear.

Ion. An electrically charged atom produced by an electrical field.

Jackshaft. An intermediate driving shaft.

Jet. A metered opening in an air or fuel passage to control the flow of fuel or air.

Journal. That part of a shaft that rotates in a bearing.

Kingpin. The pin by which a stud axle is articulated to an axle beam or steering head; also the enmeshing pin in a fifth-wheel assembly.

Kingpin Inclination. The number of degrees that the kingpin, which supports the front wheel, is tilted from the vertical.

Knock. In the engine, a rapping or hammering noise resulting from excessively rapid burning or detonation of the compressed fuel-air mixture.

Knuckle. A joint or parts carrying a hinge pin that permit one part to swing about or move in relation to another.

Laminated. Made up of thin sheets, leaves, or plates.

Laminated Leaf Spring. A spring made up of leaves of graduated size.

Landing Gear. A retractable support under the front end of a semitrailer to hold it up when it is uncoupled from the truck tractor.

Lands. Piston metal between ring grooves.

Leaf Spring. A suspension component made up of one or several layers of flat spring steel.

Lean Mixture. A fuel-air mixture that has a high proportion of air and a low proportion of fuel.

Lever. A rigid bar or beam of any shape capable of turning about one point, called the fulcrum; used for transmitting or changing force or motion.

Leverage. The mechanical advantage obtained by use of lever; also an arrangement or combination of levers.

L-Head. A type of engine with valves in the cylinder block.

Light. In the electric circuit, an electrical device that includes a wire in a gas-filled bulb that glows brightly when current passes through it; often called a lamp.

Lighting Switch. In the electrical circuit, a switch that turns light on or off.

718

DEFINITION OF TERMS – CONTINUED

LPG. Liquefied petroleum gas.

Lubrication. The process of supplying a coating of oil between moving surfaces to prevent actual contact between them. The oil film permits relative movement with little frictional resistance.

Lunette. An eye that hooks into a pintle assembly to tow vehicles.

MacPherson Strut. A front end suspension system in which the wheel assembly is attached to a long telescopic strut.

Magnet. Any body that has the ability to attract iron.

Magnetic Clutch. An electric clutch that engages and disengages the air conditioning compressor.

Magnetic Field. The space around a magnet that the magnetic lines of force permeate.

Magnetic Flux. The total amount of magnetic induction across or through a given surface.

Magnetic Pole. Focus of magnetic lines of force entering or emanating from magnet.

Magnetism. The property exhibited by certain substances and produced by electron (or electric current) motion, which results in the attraction of iron.

Magneto. A device that generates voltage surges, transforms them to high-voltage surges, and distributes them to the engine cylinder spark plugs.

Main Bearing. In the engine, the bearings that support the crankshaft.

Manifold. See Intake Manifold or Exhaust Manifold.

Master Cylinder. In the hydraulic braking system, the liquid-filled cylinder in which hydraulic pressure is developed by depression of the brake pedal.

Master Rod. In a radial engine, the rod to which all other connecting rods are attached or articulated.

Matter. Anything that has weight and occupies space.

Mechanical Efficiency. In an engine, the ratio between brake horsepower and indicated horsepower.

Mechanism. A system of parts or appliances that acts as a working agency to achieve a desired result.

Member. Any essential part of a machine or structure.

Meshing. The mating or engaging of the teeth of two gears.

Metering Rod. A small rod, having a varied diameter, operated within a jet to vary the flow of fuel through the jet.

Modulator. A pressure control or adjusting valve used in hydraulic systems of automatic transmissions.

Molecule. The smallest particle into which a chemical compound can be divided.

Motor. A device for converting electrical energy into mechanical energy.

Muffler. In the exhaust system, a device through which the exhaust gases must pass; in the muffler, the exhaust sounds are greatly reduced.

Mutual Induction. Induction associated with more than one circuit, as two coils, one of which induces current in the other as the current in the first changes.

Needle Bearing. An antifriction roller-type bearing in which the rollers have a very narrow diameter in relation to their length.

DEFINITION OF TERMS – CONTINUED

Needle Valve. The type of valve with a rod-shaped, needle-pointed valve body that works into a valve seat so shaped that the needle point fits into it and closes the passage; the needle valve in the carburetor float circuit is an example.

Negative. A term designating the point of lower potential when the potential difference between two points is considered.

Negative Terminal. The terminal from which electrons depart when a circuit is completed from this terminal to the positive terminal of generator or battery.

Neutron. A neutral-charge particle forming part of an atom.

Nonferrous Metals. All metals containing very little or no iron.

North Pole. The pole of a magnet from which the lines of force are assumed to emanate.

No-Spin Differential. A special type of differential that prevents the spinning of one of the driving wheels even if it is resting on smooth ice.

Nozzle. An orifice or opening in a carburetor through which fuel feeds into the passing airstream on its way to the intake manifold.

Octane Rating. A measure of the antiknock value of engine fuel.

Odometer. The part of the speedometer that measures, accumulatively, the number of vehicle miles traveled.

Ohm. A measure of electrical resistance. A conductor of 1-ohm resistance will allow a flow of 1 ampere of current when 1 volt is imposed on it.

Ohmmeter. A device for measuring ohms resistance of a circuit or electrical machine.

Oil. A liquid lubricant derived from petroleum and used in machinery to provide lubrication between moving parts. Also, fuel used in diesel engines.

Oil Control Rings. The lower rings on the piston that are designed to prevent excessive amounts of oil from working up into the combustion chamber.

Oil Cooler. A special cooling radiator through which hot oil passes. Air also passes through separate passages in the radiator, providing cooling of the oil.

Oil Gage. An indicating device that indicates the pressure of the oil in the lubrication system. Also, a bayonet-type rod to measure oil in the crankcase.

Oil Gallery. A pipe or drilled passageway in the engine used to transport oil from one area to another.

Oil Pan. The lower part of the crankcase in which a reservoir of oil is maintained.

Oil Pump. The pump that transfers oil from the oil pan to the various moving parts in the engine that require lubrication.

Oil Ring. Normally the bottom piston ring used to scrape excess oil off the cylinder wall.

Oil Slinger. A device mounted to a revolving shaft such that any oil passing that point will be thrown outward where it will return to the point of origin.

Oil Strainer. A strainer placed at the inlet end of the oil pump to strain out dirt and other particles, preventing these from getting into moving engine parts.

One-Way Clutch. A device used to lock a shaft in one direction while permitting rotation in the other.

Otto Cycle. The four-stroke cycle composed of intake, compression, power, and exhaust strokes.

Overflow Tank. A special tank in the cooling system (a surge tank) for hot or dry country to permit expansion and contraction of engine coolant without loss.

Overhead Valve. A valve mounted in the head above the combustion chamber. Valve in I-head engine.

720

DEFINITION OF TERMS – CONTINUED

Overload Breaker. In an electrical circuit, a device that breaks or opens a circuit if it is overloaded by a short, ground, use of too much equipment, etc.

Overrunning Clutch. A type of drive mechanism used in a starter that transmits cranking effort but overruns freely when the engine tries to drive starter. Also, a special clutch used in several mechanism that permits a rotating member to turn freely under some conditions but not under other conditions.

Parabolic Reflector. A reflector that sends all reflected light originating at the focal point outward in parallel rays.

Parallel Circuit. The electrical circuit formed when two or more electrical devices have like terminals connected together (positive to positive and negative to negative) so that each may operate independently of the other.

Parallelogram Steering Linkage. A steering configuration using two short tie rods connected to steering arms and to a long center link. The link is connected to the pitman arm on one end and the idler arm on the other.

Parking Brake. See Handbrake.

Payload. The amount of weight that can be carried by a vehicle.

PCV. Positive crankcase ventilation; a system designed to prevent crankcase vapors from being discharged into the atmosphere.

Period. The time required for the completion of one cycle.

Permanent Magnet. A piece of steel or alloy in which molecules are so alined that the piece continues to exhibit magnetism without application of external influence.

Phase. That portion of a whole period that has elapsed since the activity in question passed through zero position in a positive direction.

Pickup Coil. A device used in electronic-type distributors that sends electrical pulses to a control unit.

Pilot. A short plug at the end of a shaft to aline it with another shaft or rotating part.

Ping. A metalic rattling sound produced in the combustion chamber resulting from air-fuel mixture exploding rather than burning evenly.

Pinion. The smaller of two mating or meshing gears.

Pintle Assembly. A swivel-type assembly used to engage with a lunette for towing trailers.

Piston. In an engine, the cylindrical part that moves up and down in the cylinder.

Piston Boss. An enlarged area around the piston pinhole.

Piston Displacement. The volume displaced by the piston as it moves from the bottom to the top of the cylinder in one complete stroke.

Piston Head. A portion of the piston above the top ring.

Piston Lands. A portion of the piston between the ring grooves.

Piston Pin. The cylindrical or tubular metal pin that attaches the piston to the connecting rod; also called wrist pin.

Piston Ring. One of the rings fitted into grooves in the piston. There are two types: compression rings and oil control rings.

Piston Rod. See Connecting Rod.

Pitman Arm. The arm that is a part of the steering gear; it is connected by linkage to the wheel steering knuckle.

Pivot Inclination. See Kingpin Inclination.

Planetary Gears. Set of gears that includes a central spur gear, called the sun gear, around which revolves one or more meshing planetary gears. An internal gear, meshed with the planetary gears, completes the set.

Plies. Layers of rubber-impregnated fabric that make up the body of the tire.

DEFINITION OF TERMS – CONTINUED

Poppet. A spring-loaded ball engaging a notch. A ball latch.

Positive. A term designating the point of higher potential when the potential difference between two points is considered.

Potential. A characteristic of a point in an electric field or circuit indicated by the work necessary to bring a unit positive charge from infinity; the degree of electrification as compared to some standard (the earth, for example).

Potential Difference. The arithmetical difference between two electrical potentials; same as electromotive force, electrical pressure, or voltage.

Power. The rate of doing work.

Power Booster. A device that increases brake pedal force on master cylinder during stops.

Power Divider. A mechanism placed between dual rear axles to apportion driving effort between the two pairs of wheels to provide the maximum tractive effort.

Powerplant. The engine or power-producing mechanism on the vehicle.

Power Steering. Vehicle steering by use of hydraulic pressure to multiply the driver's steering effort so as to improve ease of steering.

Power Stroke. The piston stroke from top dead center to bottom dead center during which the fuel-air mixture burns and forces the piston down so the engine produces power.

Power Takeoff. An attachment for connecting the engine to power-driven auxiliary machinery when its use is required.

Preignition. Premature ignition of the fuel-air mixture being compressed in the cylinder on the compression stroke.

Primary Brakeshoe. The brakeshoe installed facing the front of the vehicle; usually a self-energizing shoe.

Primary Circuit. Low-voltage part of ignition system.

Primary Winding. Low-voltage winding in ignition coil.

Primer. An auxiliary fuel pump operated by hand to feed additional fuel into the engine to produce a richer mixture for starting.

Prismatic Lens. A lens with parallel grooves or flutes that deflect and distribute light rays.

Progressive Linkage. Carburetor linkage designed to open throttle valves. Primary throttle valves are first opened and, at a certain throttle position, secondary valves begin to open.

Prony Brake. A device using a friction brake to measure horsepower.

Propane. A petroleum product, sometimes referred to as LP gas, useful as engine fuel.

Propeller Shaft. The driving shaft in the power train that carries engine power from the transmission to the differential; also, the shaft that turns the propeller in amphibian vehicles.

Proportioning Valve. A valve in the brake system that prevents rear wheels from locking during harsh stops.

Proton. A basic particle of matter having a positive electrical charge, normally associated with the nucleus of the atom.

PSI. Pounds per square inch; a measure of force per unit area.

PTO. Power takeoff; a location on the transmission or transfer case from which an operating shaft from another unit can be driven.

Pulsation Damper. A unit used to smooth fuel pulsations from fuel pump to carburetor.

Pump. A device that transfers gas or liquid from one place to another.

Race. The inner or outer ring that provides a contact surface for balls or rollers to ride on.

Rack and Pinion Steering. A steering network using a pinion gear mounted on the end of the

DEFINITION OF TERMS – CONTINUED

steering shaft. The pinion engages a long rack and is connected to the steering arms via tie rods.

Radial. Pertaining to the radius of a circle.

Radial Engine. An engine with each cylinder located on the radius of a circle and with all cylinders disposed around a common crankshaft.

Radial Tire. A tire having plies parallel and at right angles to tread pattern.

Radiator. A device in the cooling system that removes heat from the coolant passing through it, permitting coolant to remove heat from the engine.

Radius. Distance from the center of a circle or from center of rotation.

Rectifier. An electrical device that changes alternating current to direct current.

Refrigerant-12. A refrigeration gas commonly used in automotive air conditioning systems.

Regulator. A device used to control output of the charging system.

Relay. In the electrical system, a device that opens or closes a second circuit in response to voltage or amperage changes in a controlling circuit.

Residual Magnetism. The magnetism retained by a material after all magnetizing forces have been removed.

Resistance. The opposition offered by a substance or body to the passage through it of an electric current.

Resistor. In an electrical system, a device made of resistance wire, carbon, or other resisting material, that has a definite value of resistance and serves a definite purpose in the system by virtue of that resistance.

Rheostat. A resistor for regulating the current by means of variable resistance.

Rich Mixture. Fuel-air mixture with a high proportion of fuel.

Rim. That part of a vehicle wheel on which the tire is mounted.

Ring Gear. A gear in the form of a ring such as the ring gear on a flywheel or differential.

Rock Position. The piston and connecting rod position (top or bottom dead center) at which the crank can rock or rotate a few degrees without appreciable movement of the piston.

Rocker Arm. A device used to direct upward motion of push rod into downward motion to open the valve. Used in overhead valve installations.

Rod. See Connecting Rod.

Rod Cap. The lower detachable part of the connecting rod that can be taken off by removing bolts or nuts so the rod can be detached from the crankshaft.

Roller Bearing. A type of bearing with rollers positioned between two races.

Rotary Engine. A piston engine in which the crankshaft is fixed and cylinders rotate around the crankshaft.

Rotor. A part that revolves in a stationary part; especially the rotating member of an electrical mechanism.

RPM. Revolutions per minute; a measure of rotational speed.

SAE. Society of Automotive Engineers.

SAE Horsepower. A measurement based upon the number of cylinders and the cylinder diameter.

Scavenging. A cleaning or blowing out action in reference to exhaust gas.

723

DEFINITION OF TERMS – CONTINUED

Sealed Beam. A special type of headlight in which the reflector and lens are sealed together to enclose and protect the filaments.

Sealed Bearing. A bearing that has been lubricated and sealed during manufacturing and cannot be lubricated during service.

Seat. The surface upon which another part rests.

Secondary Brakeshoe. A brakeshoe that is installed facing rear of car.

Secondary Wires. The wire from the coil to the distributor central tower and the spark plug wires.

Self-Energizing. A brakeshoe that develops a wedging action to assist in development of brake force.

Self-Induction. A property of a circuit that causes it to magnetically affect voltage and current in the circuit.

Semielliptical Spring. A series of leaf springs starting with the longest on top and a number of progressively shorter springs attached below.

Semitrailer. A type of trailer supported at the rear by attached wheels and at the front by the truck tractor; the truck tractor can be coupled and uncoupled by means of fifth wheel.

Separator. In the storage battery, the wood, rubber, or glass mat strip used as insulator to hold the battery plates apart.

Series Circuit. The electrical circuit formed when two or more electrical devices have unlike terminals connected together (positive to negative) so that the same current must flow through all.

Servo Action. Brakeshoes configured such that the primary brakeshoe assists in applying the secondary shoe.

Shackle. A swinging support that permits a leaf spring to vary in length as it is deflected.

Shim. A strip of copper or similar material, used under a bearing cap for example, to adjust bearing clearance.

Shimmy. Abnormal sidewise vibration, particularly of the front wheels.

Shock Absorber. A device placed at a vehicle wheel to regulate spring rebound and compression.

Short Circuit. In electrical circuits, an abnormal connection that permits current to take a short path or circuit, thus bypassing important parts of the normal circuit.

Shroud. Forward subassembly of a body or cab containing dash, cowl, and instrument panel. Also, a hood placed around a fan to improve fan action.

Shunt. Parallel connections, in a portion of an electrical circuit.

Sidewall. The section of tire between the tread and bead.

Sight Glass. A glass window in an air conditioning system used for detection of moisture or bubbles.

Slip Joint. In the power train, a variable-length connection that permits the propeller shaft to change effective length.

Sodium Valve. A valve that has been filled with sodium to increase heat transfer.

SOHC. Single overhead camshaft.

Solenoid. A coil of wire that exhibits magnetic properties when electric current passes through it.

Solid Axle. A single beam configuration that connects two wheels.

South Pole. The pole of the magnet into which it is assumed the magnetic lines of force pass.

Spark Plug. The assembly that includes a pair of electrodes which has the purpose of providing a spark gap in the engine cylinder.

DEFINITION OF TERMS – CONTINUED

Specific Gravity. The ratio of the weight of a substance to weight of an equal volume of chemically pure water at 39.2°F (4°C).

Speed. Rate of motion.

Speedometer. An indicating device, usually connected to the transmission, that indicates the speed of motion of the vehicle.

Spider. In planetary gearsets, the frame, or part, on which the planetary gears are mounted.

Spiral Bevel Gear. A bevel gear having curved teeth.

Spline. A slot or groove cut in a shaft or bore; a splined shaft onto which a hub, wheel, etc, with matching splines in its bore is assembled so the two must engage and turn together.

Spool Valve. A hydraulic control valve housing piston(s) connected by a central rod.

Sprag Unit. A form of overrunning clutch; power can be transmitted through it in one direction but not in the other.

Springs. Flexible or elastic members that support the weight of a vehicle.

Spur Gear. A gear with radial teeth parallel to the axis.

Starter. In the electrical system, the motor that cranks the engine to get it started.

Starter Solenoid. An electric relay used to deliver electrical power to the starting motor.

Starting System. The electrical system, including the starter battery, cables, switch, and controls, that has the job of starting the engine.

Static Electricity. Accumulated electrical charges, usually considered to be those produced by friction.

Stator. A part of the torque converter that stands still as torque is being multiplied, then rotates as the turbine approaches impeller speed.

Steering Gear. That part of the steering system, located at the lower end of the steering shaft, that carries the rotary motion of the steering wheel to the vehicle wheels for steering.

Steering Geometry. The difference in angles between the two front wheels and the car frame during turns; the inside wheel turns more sharply than the other wheel turns since it must travel on an arc of a smaller radius. Also called toe-out during turns.

Steering Linkage. Linkage between steering gear and vehicle wheels.

Steering System. The system of gears and linkage in the vehicle that permits the driver to turn the wheels for changing the direction of vehicle movement.

Stoplight. A red light illuminated upon application of the brake cable.

Storage Battery. A lead-acid electrochemical device that changes chemical energy into electric energy. The action is reversible; electric energy supplied to the battery stores chemical energy.

Stroke. The movement, or the distance of the movement, in either direction, of the piston travel in an engine.

Sulfation. A crystalline formation of lead sulfate on storage battery plates.

Sun Gear. In a planetary gear system, the central gear.

Supercharger. A device used in connection with engine fuel-air systems to supply more air at greater pressure to the engine, thereby increasing volumetric efficiency.

Superheat Switch. A switch used to disengage the compressor during an overheating or loss of oil condition.

Suppression. In the electrical system, the elimination of stray electromagnetic waves due to action of ignition, generator, etc, so that they cannot be detected by radio.

725

DEFINITION OF TERMS – CONTINUED

Suspension. The system of springs, etc, supporting the upper part of a vehicle on its axles or wheels.

Swaybar. A connecting bar placed between wheel supports, parallel to the axles, that prevents excessive vehicle roll or sway on turns.

Switch. In the electrical system, a device used to open or complete an electrical circuit.

Synchromesh. A name designating a certain type of transmission that has the virtue of permitting gear-ratio shifts without gear clashing.

Synchronize. To make two or more events or operations occur at the same time.

Tachometer. A device for measuring revolutions perminute.

Tactical Vehicle. A vehicle designated primarily to meet field requirements in direct connection with combat, tactical operations, and the training of troops for combat.

Taillight. Lights, usually red or amber, attached to rear of vehicle, that are used as markers.

Tailpipe. The exhaust piping running from muffler to rear of vehicle.

Tandem Axles. Two axles, one placed directly in front of the other.

Tank Sending Unit. A device in the fuel tank that provides indication of fuel level for instrument panel gage.

Taper. To make gradually smaller toward one end; a gradual reduction in size in a given direction.

Tapered Roller Bearing (Antifriction). A bearing utilizing series of tapered, hardened steel rollers operating between an outer and inner hardened steel race.

Tappet. A screw used to adjust clearance between valve stem and lifter or rocker arm.

TDC. Top dead center; the position of the piston when it reaches the upper limit of travel in the cylinder.

Teflon. A plastic with excellent self-lubricating (slippery) bearing properties.

Temper. To effect a change in hardness and strength of steel through heating and cooling.

Temperature Gage. An indicating device in the cooling system that indicates the temperature of the coolant and gives warning if excessive engine temperatures develop.

Tension. A stress caused by a pulling force.

Thermal Efficiency. The ratio between the power output and the energy in the fuel burned to produce the output.

Thermistor. A resistor whose value varies with temperature.

Thermostat. A device for automatic regulation of temperature.

Thermostatic Switch. A switch that is turned on or off by temperature change.

Third-Brush Generator. An auxiliary brush that regulates the current output of the generator by increasing or decreasing the field coil current.

Three-Quarter Trailer. Trailers, usually two-wheeled, used for light loads. The load is practically balanced on the trailer suspension, although some of the load is thrust on the truck tractor connection.

Throttle. A mechanism in the fuel system that permits the driver to vary the amount of fuel-air mixture entering the engine and thus control the engine speed.

Throttle Valve Plate. The disk in the lower part of the carburetor air horn that can be tilted to pass more or less fuel-air mixture to the engine.

Thrust. A force tending to push a body out of alinement. A force exerted endwise through a member upon another member.

DEFINITION OF TERMS – CONTINUED

Thrust Bearing. A bearing that is designed to resist axial (sideway) forces of a rotating member.

Tie Rod. A rod connection in the steering system between wheels.

TIG. Tungsten inert gas; gas tungsten arc welding.

Timed Fuel Injection. Fuel injection system that injects fuel on an individual cylinder basis and in sequence with the cylinder's intake stroke.

Timing. Refers to ignition or valve timing and pertains to the relation between the actions of the ignition or valve mechanism and piston position in the cylinder.

Timing Belt. A flexible toothed belt that, through sprockets, drives the engine camshaft.

Timing Chain. A link- or roller-type continuous chain that, through sprockets, drives the engine camshaft.

Timing Gears. A pair of helical gears that drive the engine camshaft.

Timing Marks. A pair of reference points that are used to obtain correct timing of the valves or ignition distributor of the engine.

Tire. The rubber and fabric part that is assembled on the wheel rim and filled with compressed air (pneumatic type).

Toe-In. A measurement in inches that is obtained by measuring the distances between the front tires at the forward and rearward edges and taking the difference between the two dimensions. The measurements are taken with the wheels in the straight ahead position.

Toe-Out. The normal condition that occurs with ackerman steering as the front wheels are turned. Because the inner wheel must turn sharper than the outer, the wheels are further apart at the forward edge (toe) than the rearward edge.

Tolerance. The amount of variation permitted from an exact size or measurement; the actual amount from smallest acceptable dimension to largest acceptable dimension.

Torque. A twisting or turning effort. Torque is the product, of force times the distance, from the center of rotation at which it is exerted.

Torque Converter. A special form of fluid coupling in which torque may be increased (at expense of speed).

Torque Multiplication. A term that refers to engine torque increase that occurs within a torque converter.

Torque Rod. An arm or rod used to ensure accurate alinement of an axle with the frame and to relieve springs of driving and braking stresses.

Torque-Tube Drive. The type of rear-end arrangement that includes a hollow tube that encloses the propeller shaft and also takes up stresses produced by braking and driving.

Torque Wrench. A special wrench with a dial that indicates the amount of torque in feet pound being applied to a bolt or nut.

Torsion Bar. A bar-shaped spring that is anchored on one end and operates by offering resistance as torque is applied at its other end.

Torsional Vibration. Vibration in a rotary direction; a portion of a rotating shaft that repeatedly moves ahead, or lags behind, while the remainder of the shaft is exhibiting torsional vibration.

Torus. Rotating member of fluid coupling.

Track. 1. The endless tread on which a tank rides. 2. The measurement between the center of the treads of the tires on an axle.

Tracked Vehicle. A vehicle that uses tracks instead of wheels for mobility.

Traction. The force exerted in drawing a body along a plane as when a truck tractor pulls a semitrailer.

Tractive Effort. The pushing effort the driving wheels can make against the ground, which is the

727

DEFINITION OF TERMS – CONTINUED

same as the forward thrust or push of the axles against the vehicle.

Tractor. A motor vehicle (wheeled or tracked) especially designed to tow trailers.

Trailer. A vehicle without motive power towed by a motor vehicle, designed primarily for cargo carrying.

Transfer. The auxiliary assembly for applying power to both forward and rear propeller shafts, and to front wheels as well as rear wheels.

Transfer Case. A gearbox, driven by transmission, that will provide driving force to both front and rear propeller shafts on four-wheel drive vehicle.

Transmission. The device in the power train that provides different gear ratios between the engine and driving wheels, as well as reverse.

Transmission Brake. A brake placed at the rear of the transmission, usually used for parking.

Tread. The design on the road-contacting surface of a tire that provides improved frictional contact.

Trip Odometer. An auxiliary odometer that may be reset to zero at option of driver. Used for keeping track of mileage on trips up to 1000 miles.

Truck Tractor. A motor vehicle especially designed to tow semitrailers.

Trunnion. Either of two opposite pivots or cylindrical projections from the sides of a part assembly, supported by bearings, to provide a means of swiveling or turning the part or assembly.

Trunnion Axle. A supporting axle that carries a load with other axles attached to it. Its use as a part of a bogie permits independent wheel action in a vertical plane and within designed limits.

Turbine. A mechanism containing a rotor with curved blades; the rotor is driven by the impact of a liquid or gas against the curved blades.

Turbine Engine. An engine that uses the expansive force of burning gases to spin a turbine.

Turbocharger. An exhaust-driven compressor that forces fuel and air mixture into the engine.

Turning Radius. The diameter of the circle made by a vehicle during operation with front wheels turned fully in either direction.

Turret Traversing Mechanism. A mechanism for rotating a tank turret on a horizontal plane.

Two-Stroke-Cycle Engine. An internal combustion engine requiring but two piston strokes to complete the cycle of events that produce power.

Understeer. A vehicle handling characteristic that causes a vehicle to turn less sharply than the operator intends it to.

Unit Body. A car body that has enough inherent rigidity to act as a frame also.

Universal Joint. A device that transmits power through an angle.

Unsprung Weight. Weight of a vehicle that is not supported by springs.

Updraft Carburetor. A carburetor in which air passes through it in an upward direction.

Vacuum. A space entirely devoid of matter.

Vacuum Advance. The mechanism on an ignition distributor that advances the spark in accordance with vacuum in the intake manifold.

Vacuum Brakes. Vehicle brakes that are actuated by vacuum under the control of the driver.

Vacuum Pump. A pump, used in a vacuum brake system (for example), that produces a vacuum in a designated chamber.

Vacuum Switch. In the starting system, an electric switch that is actuated by vacuum to open the starting system control circuit as the engine starts, producing a vacuum in the intake manifold.

Valve. A mechanism that can be opened or closed to allow or stop the flow of a liquid, gas, or vapor from one place to another.

728

DEFINITION OF TERMS – CONTINUED

Valve Seat. The surface, normally curved, against which the valve operating face comes to rest, to provide a seal against leakage of liquid, gas, or vapor.

Valve Seat Insert. A metal ring inserted into the valve seat; made of special metal that can withstand operating temperature satisfactorily.

Valve Spring. The compression-type spring that closes the valve when the valve-operating cam assumes a closed-valve position.

Valve Tappet. The part that rides on the valve-operating cam and transmits motion from the cam to the valve stem or push rod.

Valve Timing. Refers to the timing of valve closing and opening in relation to piston position in the cylinder.

Valve Train. The train of moving parts to the valve that causes valve movement.

Vapor Lock. A condition in the fuel system in which gasoline has vaporized, as in the fuel line, so that fuel delivery to the carburetor is blocked or retarded.

Velocity. The rate of motion or speed at any instant, usually measured in miles per hour or feet per second or minute.

Venturi. In the carburetor, the restriction in the air horn that produces the vacuum responsible for the movement of fuel into the passing airstream.

Vibration. An unceasing back and forth movement over the same path; often with reference to the rapid succession of motions of parts of an elastic body.

Vibration Damper. A weighted device that is attached to the engine crankshaft at the end opposite its power output. Its purpose is to absorb engine vibration.

Viscosity. A measure of an oil's ability to flow at a determined temperature.

Volatility. A measurement of the ease with which a liquid turns to vapor.

Volt. A unit of potential, potential difference, or electrical pressure.

Voltage Regulator. A device used in connection with a generator to keep the voltage constant and to prevent it from exceeding a predetermined maximum. (One of the three units comprising a generator regulator.)

Volumetric Efficiency. The ratio between the amount of fuel-air mixture that actually enters an engine cylinder and the amount that could enter under ideal conditions.

Volute Springs. Helical coil springs made from flat steel tapered both in width and thickness.

V-Type Engine. An engine with two banks of cylinders set at an angle to each other in the shape of a V.

Wander. To ramble or move without control from a fixed course, as the front wheels of a vehicle.

Water Jacket. A jacket that surrounds cylinders and cylinder head, through which coolant flows.

Water Manifold. A manifold used to distribute coolant to several points in the cylinder block or cylinder head.

Water Pump. In the cooling system, the pump that circulates coolant between the engine water jackets and the radiator.

Wheel Alinement. The mechanics of keeping all the parts of the steering system in correct relation with each other.

Wheel Brake. A brake that operates at the wheel, usually on a brakedrum attached to the wheel.

Wheel Cylinder. In hydraulic braking systems, the hydraulic cylinder that operates the brakeshoes when hydraulic pressure is applied in the cylinder.

Winch. A mechanism actuating a drum upon which a cable is cooled, so that when a rotating power is applied to the drum, a powerful pull is produced.

DEFINITION OF TERMS – CONTINUED

Wobble Plate. That part of a special type of pump (wobble pump) that drives plungers back and forth as it rotates to produce pumping action. It is a disk, or plate, set at an angle on a rotating shaft.

Work. The result of a force acting against opposition to produce motion. It is measured in terms of the product of the force and the distance it acts.

Worm Gear. A gear having concave, helical teeth that mesh with the threads of a worm; also called a worm wheel.

730

INDEX

Para

- Administrative vehicles 1-15
- Airbrake system:
  - Airbrake valve 34-39d
  - Air compressor 34-39a
  - Brake chamber 34-39e
  - Governor 34-39c
  - Pneumatic principle 34-38
  - Quick release valve 34-39f
  - Relay valve 34-39g
  - Slack adjuster 34-39h
  - Unloader 34-39b
- Air cooling systems:
  - Classification 2-17
  - Principle 9-13
- Air filters 4-6
- Air-fuel ratio 4-12
- Air horns 17-12
- Air injection systems 7-9
- Air-operated windshield wipers 17-16
- Air-over-hydraulic brake system:
  - Construction 34-40
  - Operation 34-41
- Air-over-hydraulic suspension system:
  - Air compressor 30-14a
  - Air shock absorbers 30-15
  - Height control valve 30-14c
  - Pressure regulator valve 30-14b
  - Purpose 30-13
- Air steering:
  - Components 33-14
  - Operation 33-15
  - Purpose 33-13
- Alarm, backup 17-13
- Alternating current generator 13-20, 13-26
- Alternators:
  - Automatic 13-23
  - Basic 13-21
  - Brushless-rotating rectifier 13-24e
  - Inductor 13-24d
  - Lundell inductor 13-24c
  - Lundell type 13-24b
  - Wound pole 13-24a
- Ammeter 17-2a
- Amperage 11-9a
- Antifreeze 9-5a
- Antiknock quality 4-40
- Atmosphere 2-22a
- Atmospheric pressure 2-22b

Para

- Automatic transmission:
  - Drive train arrangements 23-8
  - Drive train mechanisms 23-5
  - General operation 23-1
  - Hydraulic system 23-11
- Auxiliary generator 13-19
- Auxiliary heaters 17-20
- Auxiliary power receptacle 17-18
- Auxiliary transmission:
  - Operation 26-2
  - Purpose 26-1
- Axles:
  - Bogie 30-12
  - Live 29-10
  - Pusher 30-21

- Backup alarm 17-13
- Backup light system 16-14
- Ball bearing 19-8a
- Ballast resistor 15-3g
- Bars, torsion:
  - Automotive 30-2c
  - Tracked vehicle 31-1b
- Batteries:
  - Charge 12-5
  - Charging systems 13-1
  - Component parts 12-2
  - Deep cycle 12-6
  - Discharge 12-4
  - Ignition systems 15-3
  - Installation 12-10
  - Maintenance-free 12-8
  - Nickel cadmium 12-7
  - Principles of operation 15-2
  - Storage batteries 12-9
- Bead clip 32-9
- Bead lock 32-8
- Bearing lubrication 19-9
- Bearings:
  - Ball 19-8a
  - Crankshaft 3-10
  - Needle 19-8d
  - Roller 19-8b
  - Sealed 19-10
  - Sleeve type 19-7a
  - Sliding surface 19-7
  - Tapered roller 19-8c
- Bellows booster 34-35
- Bendix starter drive 14-4f
- Blackout lighting 16-9

731

INDEX – CONTINUED

Para

Bogie axles 30-12
Booster coil, magneto ignition 15-14
Boosters:
  Bellows 34-35
  Brake pedal 34-36
  Hydraulic power 34-37
  Piston 34-34
  Tandem 34-33
Brake:
  Action 34-1
  Boosters 34-33
  Contracting transmission 34-17
  Disk 34-13
  Disk transmission 34-18
  Drum 34-7c
  Fixed caliper 34-15
  Floating caliper 34-14
  Fluid 34-29
  Hill holder 34-27
  Hydraulic 34-8, 34-23
  Limiting valve 34-31
  Lines 34-28
  Lining 34-7b
  Master cylinder 34-25
  Operation 34-10
  Parking 34-19
  Pedal booster 34-36
  Pneumatic 34-9
  Power 34-32
  Proportioning valve 34-30
  Requirements 34-2
  Retardation 34-4
  Retardation point 34-5
  Rotating and nonrotating units 34-6
  Self-energizing 34-16
  Shoes 34-7a
  Vehicle stopping distance 34-3
  Wheel cylinder 34-26
Brake systems:
  Air 34-38
  Air-over-hydraulic 34-40
  Electric 34-44
  Hydraulic operation 34-24
  Hydraulic, principles 34-23
  Mechanical 34-21
  Power 34-32
  Vacuum-over-hydraulic 34-42
Brayton cycle 10-5b

Para

Camber 33-19
Camshaft 3-13
  Functions 3-13g
  Tappets 3-13h
  Timing belt 3-13e
Captive-discharge ignition 15-7
Carbon-pile regulator 13-14
Carburetion:
  Composition of air 4-8
  Downdraft 4-21
  Evaporization 4-9
  Multiple venturi 4-20
  Updraft 4-21
  Venturi effect 4-10
Carburetor systems:
  Accelerator pump circuit 4-18
  Accessory system 4-24
  Choke system 4-19
  Degasser system 4-23
  Float circuit 4-14
  High-speed enrichment 4-17
  Idle and low-speed system 4-16
  Primer system 4-22
  Throttle valve 4-13
Caster 33-18
Catalytic converters 7-8
Centrifugal governors 4-33
Centrifugal-vacuum governors 4-35
Charging systems 13-1
Choke system 4-19
Circuit breaker 13-10
Circuit configurations:
  Automotive 11-12b
  Parallel 11-12d
  Series 11-12c
  Series-parallel 11-12e
Classification of engines:
  Cooling 2-17
  Cylinder arrangements 2-19
  Design 1-19
  Valve arrangements 2-18
Clutch:
  Diaphragm 21-4c
  Elements 21-2
  Helical spring 21-4f
  Multiple disk 21-4d
  Operating system 21-3
  Overrunning 23-7
  Principles 21-1

INDEX – CONTINUED

Para

- Clutch – Continued
  - Single dry plate 21-4b
  - Wet 21-4e
- Coil springs 30-2b
- Combat vehicles 1-17
- Combustion chamber design, diesel:
  - Open chamber 5-9
  - Precombustion chamber 5-10
  - Spherical chamber 5-12
  - Turbulence chamber 5-11
- Combustion, continuous 10-6
- Commercial vehicle lighting 16-13
- Compression brake 5-38
- Compression ratio:
  - Effect of increasing 2-24c
  - Measuring 2-24b
- Compression stroke 2-6
- Compressors 10-9
- Conductors 11-4b
- Connecting rods 3-8
- Constant mesh transmission:
  - Construction 22-8
  - Gears 22-8a
  - Synchronizers 22-8b
- Contracting transmission 34-17
- Control systems:
  - Generator lockout relay 14-7
  - Key and pushbutton switch 14-5
  - Oil pressure lockout 14-8
  - Vacuum lockout switch 14-6
- Controlled differential 29-11
- Conventional differential 29-1
- Converter, catalytic 7-8
- Cooling generator 13-25
- Cooling systems:
  - Air 9-13
  - Antifreeze 9-5a
  - Closed cooling 9-12
  - Coolants 9-5
  - Corrosion resistance 9-5b
  - Engine water jackets 9-4
  - Expansion tank 9-11
  - Fan and shrouding 9-8
  - Liquid 9-3
  - Radiator pressure cap 9-10
  - Radiators 9-6
  - Thermostats 9-9
  - Water pump 9-7

Para

- Cooling systems, classification:
  - Air 2-17a
  - Liquid 2-17b
- Crankcase:
  - Air-cooled engine 3-4
  - Dilution 4-37b
  - Ventilation controls 7-7
- Crankshaft:
  - Bearings 3-10
  - Lubrication 3-9e
  - Throw arrangements 3-9c
  - Vibration 3-9d
- Cross-drive transmission:
  - Braking 24-8
  - Construction 24-3
  - Functions 24-2
  - Hydraulic system 24-7
  - Operation 24-3
  - Planetary gearing 24-5
  - Steering 24-6
  - Torque converter 24-4
- Cutout relay 13-10
- Cylinder:
  - Air-cooled engines 3-3
  - Blocks 3-1
  - Heads 3-2

- Deicing agents 4-39
- Diesel vs gasoline engine:
  - General 2-13a
  - Operation 2-13b
- Diesel fuels:
  - Cleanliness 5-2
  - Ignition quality 5-4
  - Knocking 5-5
  - Viscosity 5-3
- Diesel fuel systems:
  - Cold weather starting aids 5-31
  - Combustion chamber design 5-8
  - Engine retarder 5-37
  - Fuel filters 5-34
  - Governors 5-24
  - Injection 5-13
  - Timing devices 5-28
- Differential, controlled:
  - Construction 29-12
  - Operation 29-13
  - Purpose 29-11

INDEX – CONTINUED

Para

- Differential, conventional:
  - High-traction gears 29-3
  - Principles of operation 29-2
  - Purpose 29-1
- Differential, interwheel 29-10j
- Differential, no-spin:
  - Clutch type 29-7
  - Purpose 29-4
  - Silent type 29-6
  - Sprag type 29-5
- Differential-voltage-and-reverse-current-relay 13-19d
- Diodes 11-6
- Direct current generator 13-7
- Direct current motor 14-2
- Disk brakes 34-13
- Disk transmission 34-18
- Distributor, magneto 15-13
- Distributor, multiple contact 15-4
- Distributor-type system, diesel engine 5-16
- Dome lights 16-16b
- Drawbar 33-6
- Drawbar pull 29-15c
- Drives:
  - Eight wheel 19-17
  - Final 29-8
  - Four wheel 19-15
  - Front wheel 19-13
  - Rear wheel 19-14
  - Six wheel 19-16
- Drive train arrangements:
  - Compound planetary 23-9
  - Simpson 23-10
- Drive train mechanisms:
  - Automatic transmission 23-8
  - Brake band 23-6
  - Multiple-disk clutch 23-5
  - Overrunning clutch 23-7
- Dual horn 17-10
- Dump truck mechanisms:
  - Body control box 36-18
  - Control lever 36-19
  - Control valve and pump 36-20
  - General 36-17
  - Hydraulic cylinder 36-21
- Dynamometer 2-32

Para

- Efficiencies of engines:
  - Mechanical 2-39
  - Overall 2-40
  - Thermal 2-38
- Eight-wheel drive 19-17
- Electric brake system:
  - Construction 34-44
  - Operation 34-45
- Electric windshield wipers 17-15
- Electrical system:
  - Amperage 11-9a
  - Batteries 12-1
  - Battery ignition 15-2
  - Carbon-pile regulator 13-14
  - Circuit breaker 13-10
  - Circuit configurations 11-12
  - Conductors 11-4b
  - Cutout relay 13-10
  - Diodes 11-6
  - Electricity, composition 11-2
  - Electromagnetic induction 11-15
  - Electromagnetism 11-14
  - Electron theory 11-3
  - Fuse 16-8b
  - Ignition 10-21
  - Insulators 11-4c
  - Lighting system 16-1
  - Magnetic field 11-13
  - Magneto 15-9
  - Matter, composition 11-1
  - Motor, direct current 14-2
  - Ohm's law 11-11
  - Resistance 11-10
  - Semiconductor devices 11-5
  - Solid-state voltage regulator 13-29
  - Starter, motor drives 14-4
  - Starting 10-22
  - Step voltage control 13-16b
  - Transistorized point regulator 13-28
  - Transistors 11-8
  - Third-brush regulator 13-16
  - Vibrating point regulator 13-13, 13-27
  - Voltage 11-9b
  - Zener diodes 11-7
- Electromagnetic induction 11-15
- Electromagnetism 11-14

INDEX – CONTINUED

Para

- Emission control system 7-5
- Energy 2-28
- Engine:
  - Classifications 2-17
  - Compression ratio 2-24
  - Connecting rods 3-8
  - Crankcase 3-1e
  - Crankshaft 3-9
  - Cylinder block 3-1
  - Cylinder head 3-2
  - Efficiency 2-38
  - Exhaust manifold 7-2
  - Exhaust stroke 2-8
  - Exhaust valve 2-3
  - F-head 2-18c
  - Flywheel 2-10e, 3-11
  - Horizontal opposed 2-19c
  - Ignition timing 2-25
  - I-head 2-18a
  - In-line 2-19a
  - Intake manifold 4-5
  - L-head 2-18a
  - Measurements 2-20
  - Oils 8-4
  - Operation 2-1
  - Radial 2-19d
  - T-head 2-18a
  - Valve-operating mechanisms 3-14
  - V-type 2-19b
  - Water jackets 9-4
- Ether injection system 5-33
- Evaporation, fuel 7-11
- Exhaust:
  - Manifold 7-2
  - Port 2-3
  - Stroke 2-8
  - Valve 2-3
- Exhaust emissions, control of 7-6
- Exhaust gas recirculation system 7-10
- Expansion tank 9-11

- Fan 9-8
- Field intensity 13-5
- Field winding configurations 13-7
- Fifth wheel 38-3
- Filters, air 4-6
- Final drive 29-8

Para

- Fixed caliper 34-15
- Floating caliper 34-14
- Fluid, brake 34-29
- Fluid couplings:
  - Operation 21-6
  - Principles 21-5
- Flywheel 2-10e, 3-11
- Force-feed system 8-19
- Four-stroke cycle operation 2-5, 2-6
- Four-wheel drive 19-15
- Four-wheel driving and steering 33-16
- Frame and body, tracked vehicle 35-5
- Frame and body, wheeled vehicle:
  - Brackets and hangers 35-4
  - Integrated (monocoque) 35-2
  - Separate 35-1
  - Trucks (ladder) 35-3
- Front-wheel drive 19-13

- Gages:
  - Fuel 17-3
  - Oil pressure 17-4
  - Temperature 17-5
- Gaskets 19-12
- Gasoline:
  - Antiknock quality 4-40
  - Crankcase dilution 4-37b
  - Deicing agents 4-39
  - Fuel distribution 4-37d
  - Origin 4-36
  - Purity 4-38
  - Starting ability 4-37a
  - Vapor lock 4-37c
  - Volatility 4-37
- Gasoline and water tankers:
  - Considerations 36-16
  - General 36-13
  - Semitrailer 36-14
  - Tank truck 36-15
- Gasoline engine:
  - Continuous fuel injection systems 4-27
  - Timed fuel injection systems 4-26
- Gas turbine engine:
  - Air inlet section 10-8
  - Brayton cycle 10-5b

INDEX – CONTINUED

Para

Gas turbine engine – Continued
  Combustion chamber 10-10
  Compressors 10-9
  Continuous combustion 10-6
  Cycle characteristics 10-4
  Electrical system 10-20
  Exhaust 10-13
  Fuel system 10-14
  History 10-1
  Introduction 10-2
  Lubrication system 10-17
  Operation 10-3
  Otto cycle 10-5a
  Recouperator 10-11
  Thermal comparison 10-7
  Turbines 10-12
Gear drives 29-9
Gear reduction starter 14-4b
Gears:
  Bevel 19-4d
  External 19-3e
  Helical 19-4b
  Herringbone 19-4c
  Internal 19-3e
  Mechanical advantage 19-3b
  Mechanical efficiency 19-3d
  Spur 19-4a
  Steering 33-3
  Torque ratio 19-3a
  Worm 19-4e
Gearshift linkage:
  Mechanical 22-9
General transport vehicles 1-19a
Generators:
  Alternating current 13-20, 13-26
  Cooling 13-25
  Direct current 13-7
  Field winding 13-7
  Generator speed 13-4
  Main and auxiliary system 13-19
  Multiple loop 13-3
  Paralleling 13-18
  Regulation 13-11
  Reverse-series field 13-12
  Shunt wound 13-8
  Simple single loop 13-2
  Split-series field 13-17
  Third-brush, control 13-16
  Third-brush regulation 13-15

Para

Generator lockout relay 14-7
Generator speed 13-4
Glare elimination 16-6
Governors, diesel engines:
  Actuation 5-25
  Mechanical (centrifugal) 5-26
  Vacuum 5-27
Governors, gasoline engines:
  Centrifugal 4-33
  Centrifugal-vacuum 4-35
  Velocity-vacuum 4-34
Grade ability 29-15b
Ground contact 1-20

Headlamp control system 16-7
Headlights 16-4
Heater 17-19
Height control valve 30-14c
Hill holder, brake 34-27
History of military vehicles:
  Post-World War II 1-12
  Pre-World War II 1-11
Horizontal opposed engine 2-19c
Horns:
  Air 17-12
  Backup alarm 17-13
  Controls 17-11
  Dual 17-10
  Operation 17-9
Horsepower:
  Dynamometer 2-32
  Gross and net 2-35
  Indicated 2-36
Hulls:
  Amphibious trucks 35-7
  Armored tanks 35-5
  Tracked vehicles 35-8
  Unarmored and self-propelled guns 35-6
Hydraulic brake system:
  Brake fluid 34-29
  Brake lines 34-28
  Hill holder 34-27
  Limiting valve 34-31
  Master cylinder 34-25
  Operation 34-24
  Principles 34-23
  Proportioning valve 34-30
  Wheel cylinder 34-26

INDEX – CONTINUED

Para

Hydraulic jack, simple:
  Construction 20-8
  Mechanical advantage 20-10
  Operation 20-9
Hydraulic power booster 34-37
Hydraulic principles:
  Liquid versus gas 20-1
  Mechanical advantage 20-3
  Pascal's law 20-2
Hydraulic system, automatic transmission:
  Converter feed circuit 23-13
  Hydraulic pump 23-12a
  Modulation 23-12d
  Oil sump and filter 23-12b
  Purpose 23-11
  Range control system 23-14
  Regulator valve 23-12c
  Supply system 23-12

Ignition:
  Battery 15-3
  Timing 2-25
Ignition system, gas turbine engine 10-21
Ignition systems, magneto:
  Booster coil 15-14
  Distributor 15-13
  Electrical energy 15-10
  General 15-9
  Interrupting device 15-12
  Switches 15-15
  Transforming device 15-11
Ignition systems, waterproofing 15-16
Ignition timing devices 15-8
I-head engine 2-18a
Independent axle suspension system:
  Driven 30-7
  Freewheeling 30-6
Infrared lighting:
  Active system 16-12a
Injection systems, diesel:
  Passive system 16-12b
  Distributor type 5-16
  Ether 5-33
  Fuel 5-13
  Multiple unit 5-14
  Pressure-timed 5-18
  PSB distributor 5-19

Para

Injection systems, diesel – Continued
  Unit 5-17
  Wobble plate pump 5-15
In-line engines 2-19a
Instrument lights 16-16a
Instruments:
  Ammeter 17-2a
  Fuel gage 17-3
  Indicator lamp 17-2c
  Panel 17-1
  Pressure gage 17-4
  Speedometer 17-6
  Tachometer 17-6
  Temperature gage 17-5
  Voltmeter 17-2b
Insulators 11-4c
Intake:
  Manifold 4-5
  Port 2-3
  Stroke 2-5
  Valve 2-3
Intake manifold flame heater system 5-32
Interference, radio 18-2
Internal combustion engine 2-11a
Interrupting device 15-12
Interwheel differential 29-10j

Jacobs engine brake 5-40

Key and pushbutton switch control circuit 14-5
Kingpin and plate 38-2
Kingpin inclination 33-20
Knocking, diesel engine 5-5

Lamps 16-2
Landing gear 38-4, 38-8
Leaf springs 30-2a
L-head engines 2-18a
Light beams 16-3
Lighting system:
  Backup 16-14
  Beams 16-3
  Blackout 16-9
  Commercial vehicle 16-13
  Glare elimination 16-6
  Headlamp control 16-7

737

INDEX – CONTINUED

Para

Lighting system – Continued
  Headlights 16-4
  Infrared 16-12
  Lamps 16-2
  Overload breakers 16-8
  Road illumination 16-5
Lights:
  Backup 16-14
  Blackout 16-9
  Dome 16-16b
  Head 16-4
  Infrared 16-12
  Instrument 16-16a
  Parking 16-16c
  Stop 16-15
  Turn signal 16-13
Lines, brake 34-28
Lining, brake 34-7b
Live axles:
  Front wheel 29-10l
  Independent suspension 29-10f
  Rear, dual ratio 29-10h
  Rear, double reduction 29-10g
  Rear, double reduction, dual ratio 29-10i
  Rear, full floating 29-10e
  Rear, plain 29-10b
  Rear, semifloating 29-10c
  Rear, three-quarter floating 29-10d
Liquefied petroleum gas 6-1
Liquid cooling systems:
  Coolants 9-5
  Engine water jacket 9-4
  Expansion tank 9-11
  Fan and shrouding 9-8
  Radiator 9-6
  Radiator pressure cap 9-10
  Thermostat 9-9
  Water pump 9-7
Lubrication system:
  API rating system 8-5
  Bearing 19-9
  Components 10-19
  Crankshaft 3-9e
  Detergent oils 8-8
  Engine oils 8-4
  Force-feed system 8-19
  Full force-feed system 8-20
  Multiweight oils 8-7

Para

Lubrication system – Continued
  Oil as a lubricant 8-2, 10-18
  Oil coolers 8-14
  Oil filters 8-13
  Oil level indicator 8-15
  Oil pumps 8-9
  Oil strainer 8-12
  Pressure regulator 8-16
  Splash and force-feed system 8-18
  Splash system 8-17
  Viscosity 8-6
Lunette 38-7

Muffler 7-4
Magnetic field 11-13
Magneto ignition systems:
  Booster coil 15-14
  Distributor 15-13
  Electrical energy 15-10
  Switches 15-15
Main generator 13-19
Main generator system 13-19
Maintenance-free battery 12-8
Manifold:
  Exhaust 7-2
  Intake 4-5
Manifold heat control valve 7-3
Master cylinder 34-25
Matching towing vehicle to trailer:
  Brake system 38-13
  Electrical system 38-12
  Load and performance 38-14
Matter, composition 11-1
Mechanical brake system:
  Hookup 34-22
  Means of actuation 34-21
Mechanical (centrifugal) governors 5-26
Military vehicles, features 1-14
Motors:
  Automotive starting 14-3
  Direct current 14-2
Multifuel engines:
  Authorized fuels 5-6
  Fuel density compensator 5-7
Multiple-loop generator 13-3

INDEX – CONTINUED

Para

- Needle bearing 19-8d
- No-spin differential 29-4

- Ohm's law 11-11
- Oil:
  - Coolant 8-3
  - Coolers 8-14
  - Detergent 8-8
  - Engine 8-4
  - Filters 8-13
  - Level indicator 8-15
  - Lubricant 8-2
  - Multiweight 8-7
  - Strainer 8-12
- Oil pressure gage 17-4
- Oil pressure lockout circuit 14-8
- Oil pumps:
  - Gear 20-4
  - Internal-external gear 20-7
  - Rotary 20-5
  - Vane 20-6
- Oil seals:
  - Synthetic rubber 19-11a
  - Wick 19-11b
- Operation, engine:
  - Compression stroke 2-6
  - Exhaust stroke 2-8
  - Intake stroke 2-5
  - Power stroke 2-7
- Otto cycle 10-5a
- Overdrive:
  - Configurations 26-6
  - Control system 26-9
  - Operation 26-8
  - Purpose 26-5
  - Unit construction 26-7
- Overload breakers:
  - Circuit breaker 16-8a
  - Fuse 16-8b
- Overrunning clutch 23-7, 14-4c

- Panel, instrument 17-1
- Parallel circuits 11-12d
- Paralleling generators 13-18
- Parking brake 34-19
- Parking lights 16-16c

Para

- Pascal's law 20-2
- Pedal shift 14-4d
- Performance factors 29-15
- Petroleum gas, liquefied 6-1
- Piston:
  - Booster 34-35
  - Pins 3-7
  - Rings 3-6
- Piston engine operation 2-1
- Piston rings:
  - Compression 3-6b
  - Oil control 3-6b
- Pistons 3-5
- Planetary gear system 19-5
  - Six basic laws 19-6
- Plate and kingpin 38-2
- Power:
  - Horsepower 2-29
- Power braking system 34-32
- Power divider 29-10k
- Power steering, hydraulic:
  - Components 33-10
  - Configurations 33-12
  - Operation 33-11
  - Purpose 33-9
- Power stroke 2-7
- Power takeoff:
  - Auxiliary 36-4
  - Construction 36-2
  - Purpose 36-1
  - Transfer case 36-5
  - Transmission 36-3
  - Usage 36-6
- Power trains:
  - Bearings 19-7, 19-8
  - Gears, principles 19-3
  - Gears, types 19-4
  - Purpose 19-1
  - Track vehicles 19-18
- Power trains, wheeled vehicles:
  - Differential 29-1
  - Drive, front wheel 19-13
  - Final drive 29-8
  - Propeller shaft 28-1
  - Slip joints 28-2
  - Transfer assembly 27-1
  - Universal joints 28-3
- Precombustion chamber 5-10

INDEX – CONTINUED

Para

Pressure regulator 8-16
Pressure regulator valve 30-14b
Pressure-timed injection system, diesel engine 5-18
Pumps, diesel engines:
  Gear type 5-23
  Plunger type 5-22
  Vane type 5-21
Prony brake 2-31
Propane fuel system:
  Liquefied petroleum gas 6-1
  Operation 6-2
Propeller shafts:
  Construction 28-1b
  Purpose 28-1a
PSB distributor injection system, diesel engine 5-19
Pusher axles 30-21

Radial engine 2-19d
Radiator pressure cap 9-10
Radiators 9-6
Radio, automotive:
  Installation 18-1a
  Interference 18-1c
  Power requirements 18-1b
  Suppression of interference 18-5
Radio interference:
  Body noises 18-4
  Generator noises 18-3
  Ignition noises 18-2
Rated speed 2-34
Ratio, air-fuel 4-12
Ratio, compression 2-24
Rear axles:
  Rear, dual ratio 29-10h
  Rear, double reduction 29-10g
  Rear, double reduction, dual ratio 29-10i
  Rear, full floating 29-10e
  Rear, plain 29-10b
  Rear, semifloating 29-10c
  Rear, three-quarter floating 29-10d
Rear-wheel drive 19-14
Recirculating system exhaust gas 7-10
Recouperator 10-11
Refrigeration:
  Ambient temperature 37-1
  Compressor 37-7
  Condensor 37-8

Para

Refrigeration – Continued
  Cycle 37-3
  Evaporator 37-6
  Expansion system 37-5
  Gases 37-2
  Oil 37-9
  Receiver 37-4
Regulation generator 13-11
Regulator:
  Carbon-pile 13-14
  Solid-state voltage 13-29
  Third-brush 13-16
  Transistorized point 13-28
  Vibrating point 13-13, 13-27
Resistance 11-10
Resistor, ballast 15-3g
Retarder system:
  Brake 34-4
  Compression brake 5-38
  Hydraulic 5-39
  Jacobs engine brake 5-40
  Purpose 5-37
Reverse-series field generator 13-12
Road illumination 16-5
Rods, connecting 3-8
Roller bearings 19-8b

Sealed beam 16-4b
Sealed bearing 19-10
Self-energizing brakes 34-16
Semiconductor devices 11-5
Semitrailers:
  Converted to full 38-9b
  Description 1-19e, 38-1
  Fifth wheel 38-3
  Kingpin and plate 38-2
  Landing gear 38-4
Series circuits 11-12c
Series-parallel circuits 11-12e
Shifting, automatic transmission 23-3
Shock absorbers:
  Air 30-15
  Direct acting 30-18c
  Double acting 30-17b
  Purpose 30-16
  Single acting 30-17a
  Single acting, cam operated 30-18a
  Vane type 30-18b

INDEX – CONTINUED

Para

- Shoes, brake 34-7a
- Shunt-wound generator 13-8
- Simple single-loop generator 13-2
- Simpson drive train 23-10
- Six-wheel drive 19-16
- Sleeve-type bearing 19-7a
- Sliding gear transmission:
  - Construction 22-5
  - Gears 22-5a
  - Power flow 22-7
  - Shifting 22-6
  - Shift rails and forks 22-5c
  - Shafts and bearings 22-5b
- Sliding surface bearing 19-7
- Slip joints 28-2
- Solenoid shift 14-4e
- Solid-state ignition 15-6
- Solid-state voltage regulator 13-29
- Spark plugs 15-3f
- Special equipment vehicles 1-19b
- Special purpose vehicles 1-19c
- Speedometer 17-6
- Spherical chamber 5-12
- Splash and force-feed lubrication system 8-18
- Splash lubricating system 8-17
- Split-series-field generator 13-17
- Spring, coil 30-2b
- Starter motor drives 14-4
- Starting aids, cold weather 5-31
- Starting motor 14-3
- Starting system 10-22, 14-1
- Step voltage control 13-16b
- Steering gears:
  - Cam and lever 33-6
  - Rack and pinion 33-8
  - Worm and nut 33-7
  - Worm and roller 33-5
  - Worm and sector 33-4
- Steering systems:
  - Ackerman 33-1a
  - Air 33-13
  - Fifth wheel 33-1b
  - Four wheel 33-16
  - Geometry 33-17
  - Hydraulic 24-7
  - Independent suspension linkage 33-3

Para

- Steering systems – Continued
  - Power 33-9
  - Solid axle steering linkage 33-2
  - Steering gears 33-4
  - Toe-out 33-17
- Steering through cross-drive transmission 24-6
- Stoplight system 16-15
- Storage batteries 12-9
- Subtransmission:
  - Automatic 26-4b
  - Manual 26-4a
  - Purpose 26-3
- Superchargers 4-31
- Suppression, radio:
  - Applications 18-6
  - Bonding 18-5d
  - Capacitors 18-5b
  - Filters 18-5c
  - Resistor-suppressors 18-5a
  - Shielding 18-5e
- Suspension systems, tracked vehicles:
  - Horizontal valve spring suspension 31-5
  - Hydraulic lockout system 31-9
  - Hydromechanical lockout system 31-10
  - Idler wheels and rollers 31-3
  - Road wheels 31-2
  - Shock absorbers 31-7
  - Spade system 31-11
  - Springs 31-1
  - Suspension lockout system 31-8
  - Suspension snubbers 31-6
  - Torsion bar suspension 31-4
- Suspension systems, wheeled vehicles:
  - Air-over-hydraulic 30-13
  - Axles 30-11
  - Bogie axles 30-12
  - Heavy vehicle 30-10
  - Independent axle 30-5
  - Live axle 30-4
  - MacPherson 30-8
  - Purpose 30-1
  - Solid axle 30-3
  - Spring configurations 30-2
- Swaybars 30-20
- Switch, headlamp control 16-7a
- Synthetic rubber oil seal 19-11a

INDEX – CONTINUED

Para

- Tachograph operation 17-7
- Tachometer 17-6
- Tactical vehicles 1-16
- Tandem booster 34-33
- Tapered roller bearing 19-8c
- Temperature gage 17-5
- T-head engine 2-18a
- Thermostat 9-9
- Third-brush generator, control 13-16
- Third-brush regulation 13-15
- Three-quarter trailers:
  - Description 38-5
  - Drawbar 38-6
  - Landing gear 38-8
  - Lunette 38-7
- Throttle body injection 4-28
- Timing:
  - Belt 3-13e
  - Ignition 2-25
  - Valve 2-26
- Timing device 5-28
- Timed fuel injection systems:
  - Electronic 4-26c
  - Mechanical 4-26b
- Tire inflation system:
  - Construction 36-12
  - Purpose 36-11
- Tires:
  - Assembly 32-10
  - Bus 32-11c
  - Combat 32-11b
  - Earthmover 32-11f
  - Grader 32-11g
  - Identification 32-18
  - Ozone-resistant rubber 32-13
  - Passenger 32-11d
  - Rock-service 32-11e
  - Runflat 32-11h
  - Tactical 32-11a
  - Treads 32-12
  - Truck 32-11c
  - Tube flaps 32-15
  - Tubes, types 32-14
  - Valves 32-16
- Toe-in 33-21
- Toe-out 33-17
- Torque 2-30
- Torque arms 30-19

Para

- Torque converters:
  - Cross-drive transmission 24-4
  - Lockup 21-9
  - Operation 21-8
  - Principles 21-7
- Torque-horsepower-speed (RPM) relationship 2-33
- Torque ratio gear 19-3a
- Torsion bars:
  - Automotive 30-2c
  - Tracked vehicles 31-1b
- Tracking 33-22
- Tracks:
  - Characteristics 32-19
  - Pad types 32-23
  - Pin connected 32-21
  - Sectional band 32-20
  - Shoe types 32-22
- Tractive factor 29-15a
- Trailers:
  - Full 38-9
  - Landing gear 38-4
  - Semi 38-1
  - Tank 36-15
  - Three-quarter 38-5
  - Trailer matching to towing vehicle 38-12
- Transfer assemblies:
  - Conventional 27-3
  - Differential type 27-5
  - Divided engine torque 27-1
  - Double-sprag unit 27-10
  - High- and low-gear range 27-2
  - Positive traction 27-7
  - Single-sprag unit 27-9
  - Sprag unit 27-8
  - Typical operation 27-4
- Transforming device 15-11
- Transistorized point ignition 15-5
- Transistorized point regulator 13-28
- Transistors 11-8
- Transmissions:
  - Automatic 23-1
  - Auxiliary 26-1
  - Constant mesh 22-8
  - Cross-drive 24-1
  - Sliding gear 22-5
  - Subtransmissions 26-3
  - X1100 series cross-drive 25-1

INDEX – CONTINUED

	Para
Treads, tire:	
Cross country	32-12b
Desert	32-12g
Earthmover	32-12e
Mud and snow	32-12a
Regular	32-12c
Rock service	32-12d
Traction	32-12f
Tubes:	
Bullet resisting	32-14c
Combat	32-14b
Identification	32-18
Standard	32-14a
Tube flaps	32-15
Turbines	10-12
Turbochargers	4-30
Turbulence chamber	5-11
Turn signal system	16-13
Two-stroke cycle engine, diesel	2-14
Underwater ventilating system:	
Applications	36-25
Purpose	36-24
Unit injection system, diesel engine	5-17
Universal joints:	
Ball and trunnion	28-5b
Bendix-Weiss	28-7b
Constant velocity	28-6
Double cross and roller	28-7d
Journal type	28-5a
Operation	28-4
Purpose	28-3
Rzeppa	28-7a
Tracta	28-7c
Vacuum gage	17-8
Vacuum governors	5-27
Vacuum lockout switch	14-6
Vacuum-over-hydraulic brake system:	
Construction	34-42
Operation	34-43
Vacuum windshield wipers	17-14
Valves:	
Airbrake	34-39d
Cap	32-17b
Clamp-in double bent	32-16h

	Para
Valves – Continued	
Clamp-in tubeless tire	32-16f
Core	32-17a
Cured-in	32-16c
Cured-on	32-16a
Cured-on large bore	32-16b
Exhaust	2-3
Guides	3-12d
Height control	30-14c
Intake	2-3
Large bore tubeless tire	32-16g
Operating mechanism	3-14
Pressure regulator	30-14b
Quick release	34-39f
Relay	34-39h
Rotators	3-12f
Seats	3-12c
Snap-in tubeless tire	32-16e
Springs, retainers, and seals	3-12e
Spud mounted	32-16d
Tappet	3-13h
Timing	2-26
Valve timing	2-26
Valve train	2-9
Vapor lock	4-37c
Vehicle stopping distance	34-3
Velocity-vacuum governor	4-34
Ventilation control, crankcase	7-7
Ventilation system, fuel tank	4-4
Venturi effect	4-10
Vibrating point regulator	13-13, 13-27
Viscosity	8-6
Voltage	11-9b
Voltmeter	17-2b
Volumetric efficiency	2-23
V-type engine	2-19b
Water jackets	9-4
Waterproofed generators	13-9
Waterproofed ignition systems	15-6
Water pump	9-7
Wheel alinement:	
Camber	33-19
Caster	33-18
Kingpin inclination	33-20
Steering geometry	33-17
Toe-in	33-21
Toe-out	33-17

743

INDEX – CONTINUED

Para

- Wheel center section:
  - Disk 32-1
  - Pressed and cast spoked 32-2
  - Wire 32-3
- Wheel cylinder 35-26
- Wheeled vehicles:
  - Drawbar pull 29-15c
  - Grade ability 29-15b
  - Performance factors 29-15
  - Power trains 19-1
  - Suspension system 30-1
- Wheel rims:
  - Drop center 32-4
  - Safety 32-6
  - Semidrop center 32-5
  - Split 32-7
- Wick seals 19-11b
- Winches:
  - Level wind 36-10
  - Mounting 36-8
  - Operation 36-9
  - Purpose 36-7
- Windshield wipers:
  - Air operated 17-16
  - Arm and blade 17-17
  - Electric 17-15
  - Vacuum 17-14

Para

- Wiring, automotive:
  - Connectors 17-25
  - Harnesses 17-22
  - Harness identification 17-23
  - Terminal ends 17-24
- Wobble plate pump, diesel engine 5-15
- Wrecker truck equipment:
  - General 36-22
  - Operation 36-23

- X1100 series cross-drive transmission:
  - Control pumps 25-7b
  - Final drive 25-8
  - Function 25-2
  - General 25-1
  - Planetary gearing 25-5
  - Servo sleeve 25-7c
  - Servo valve 25-7d
  - Steering 25-6
  - Stroke limiter valve 25-7e
  - Supercharge check valves 25-7a
  - Torque converter 25-4

- Zener diodes 11-7

By Order of the Secretary of the Army:

JOHN A. WICKHAM, JR.
General, United States Army
Chief of Staff

Official:

MILDRED E. HEDBERG
Brigadier General, United States Army
The Adjutant General

Distribution:

To be distributed in accordance with DA Form 12-37, Operator, Organizational, Direct and General Support Maintenance requirements for Carrier, Personnel, M113A1, Command Post, M577A1, Mortar, M106A1; Mortar, M125A1; Flame Thrower, M132A1; Gun, M741; Recovery Vehicle, XM1059. Also, to be distributed in accordance with DA Form 12-38, Operator, Organizational, Direct and General Support Maintenance requirements for Truck, Utility, 1/4-ton, 4x4, M151-series.

☆U.S. GOVERNMENT PRINTING OFFICE: 1985-554-019/20181

745

RECOMMENDED CHANGES TO EQUIPMENT TECHNICAL PUBLICATIONS

THEN. . JOT DOWN THE DOPE ABOUT IT ON THIS FORM, CAREFULLY TEAR IT OUT, FOLD IT AND DROP IT IN THE MAIL!

SOMETHING WRONG WITH THIS PUBLICATION?

FROM: (PRINT YOUR UNIT'S COMPLETE ADDRESS)
Your Mailing Address

DATE SENT
Date you fill out this form

PUBLICATION NUMBER	PUBLICATION DATE	PUBLICATION TITLE
TM 9-8000	October 1985	Principles of Automotive Vehicles

BE EXACT . . . PIN-POINT WHERE IT IS

PAGE NO	PARA-GRAPH	FIGURE NO	TABLE NO	IN THIS SPACE TELL WHAT IS WRONG AND WHAT SHOULD BE DONE ABOUT IT:
2-31				For item 2, change NSN to read: 5835-00-134-9186. Reason: Accuracy

SAMPLE

PRINTED NAME, GRADE OR TITLE, AND TELEPHONE NUMBER
PFC. Walter Roberts

SIGN HERE
PFC. Walter Roberts

DA FORM 1 JUL 79 2028-2

PREVIOUS EDITIONS ARE OBSOLETE.

P S --IF YOUR OUTFIT WANTS TO KNOW ABOUT YOUR RECOMMENDATION MAKE A CARBON COPY OF THIS AND GIVE IT TO YOUR HEADQUARTERS

RECOMMENDED CHANGES TO EQUIPMENT TECHNICAL PUBLICATIONS

THEN. . JOT DOWN THE DOPE ABOUT IT ON THIS FORM. CAREFULLY TEAR IT OUT. FOLD IT AND DROP IT IN THE MAIL'

SOMETHING WRONG WITH THIS PUBLICATION?

FROM: (PRINT YOUR UNIT'S COMPLETE ADDRESS)

DATE SENT

PUBLICATION NUMBER TM 9-8000	PUBLICATION DATE October 1985	PUBLICATION TITLE Principles of Automotive Vehicles

BE EXACT . . . PIN-POINT WHERE IT IS

PAGE NO	PARA-GRAPH	FIGURE NO	TABLE NO

IN THIS SPACE TELL WHAT IS WRONG AND WHAT SHOULD BE DONE ABOUT IT:

PRINTED NAME, GRADE OR TITLE, AND TELEPHONE NUMBER

SIGN HERE

DA FORM 1 JUL 79 2028-2

PREVIOUS EDITIONS ARE OBSOLETE.

P S --IF YOUR OUTFIT WANTS TO KNOW ABOUT YOUR RECOMMENDATION MAKE A CARBON COPY OF THIS AND GIVE IT TO YOUR HEADQUARTERS

THE METRIC SYSTEM AND EQUIVALENTS

LINEAR MEASURE

1 Centimeter=10 Millimeters=0.01 Meters=0.3937 Inches
1 Meter=100 Centimeters=1000 Millimeters=39.37 Inches
1 Kilometer=1000 Meters=0.621 Miles

WEIGHTS

1 Gram=0.001 Kilograms=1000 Milligrams=0.035 Ounces
1 Kilogram=1000 Grams=2.2 Lb
1 Metric Ton=1000 Kilograms=1 Megagram=1.1 Short Tons

LIQUID MEASURE

1 Milliliter=0.001 Liters=0.0338 Fluid Ounces
1 Liter=1000 Milliliters=33.82 Fluid Ounces

SQUARE MEASURE

1 Sq Centimeter=100 Sq Millimeters=0.155 Sq Inches
1 Sq Meter=10,000 Sq Centimeters=10.76 Sq Feet
1 Sq Kilometer=1,000,000 Sq Meters=0.0386 Sq Miles

CUBIC MEASURE

1 Cu Centimeter=1000 Cu Millimeters=0.06 Cu Inches
1 Cu Meter=1,000,000 Cu Centimeters=35.31 Cu Feet

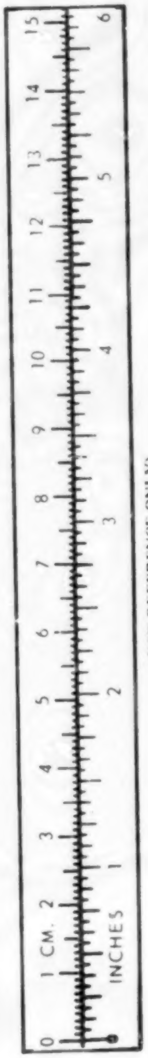
TEMPERATURE

5/9 (°F – 32) = °C
212° Fahrenheit is equivalent to 100° Celsius
90° Fahrenheit is equivalent to 32.2° Celsius
32° Fahrenheit is equivalent to 0° Celsius
9/5 C° +32=F°

APPROXIMATE CONVERSION FACTORS

TO CHANGE	TO	MULTIPLY BY
Inches	Centimeters	2.540
Feet	Meters	0.305
Yards	Meters	0.914
Miles	Kilometers	1.609
Square Inches	Square Centimeters	6.451
Square Feet	Square Meters	0.093
Square Yards	Square Meters	0.836
Square Miles	Square Kilometers	2.590
Acres	Square Hectometers	0.405
Cubic Feet	Cubic Meters	0.028
Cubic Yards	Cubic Meters	0.765
Fluid Ounces	Milliliters	29.573
Pints	Liters	0.473
Quarts	Liters	0.946
Gallons	Liters	3.785
Ounces	Grams	28.349
Pounds	Kilograms	0.454
Short Tons	Metric Tons	0.907
Pound-Feet	Newton-Meters	1.356
Pounds per Square Inch	Kilopascals	5.895
Miles per Gallon	Kilometers per Liter	0.425
Miles per hour	Kilometers per Hour	1.609

TO CHANGE	TO	MULTIPLY BY
Centimeters	Inches	0.394
Meters	Feet	3.280
Meters	Yards	1.094
Kilometers	Miles	0.621
Square Centimeters	Square Inches	0.155
Square Meters	Square Feet	10.764
Square Meters	Square Yards	1.196
Square Kilometers	Square Miles	0.385
Square Hectometers	Acres	2.471
Cubic Meters	Cubic Feet	35.315
Cubic Meters	Cubic Yards	1.308
Milliliters	Fluid Ounces	0.034
Liters	Pints	2.113
Liters	Quarts	1.057
Liters	Gallons	0.264
Grams	Ounces	0.035
Kilograms	Pounds	2.205
Metric Tons	Short Tons	1.102
Newton-Meters	Pound-Feet	0.738
Kilopascals	Pounds per Square Inch	0.145
Kilometers per Liter	Miles per Gallon	2.354
Kilometers per Hour	Miles per Hour	0.621



(FOR REFERENCE ONLY)

TA089991

778

BEST COPY AVAILABLE